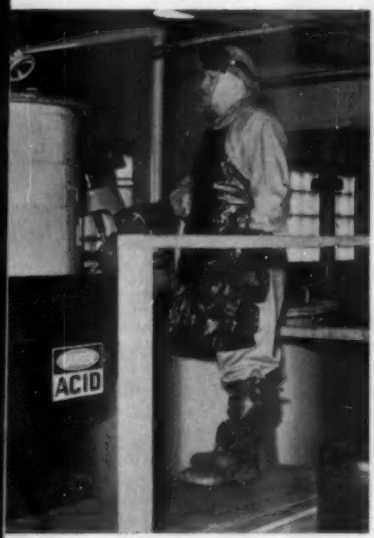
NOVEMBER 1958

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 50 • NO. 11



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SAFE
(And the editors, too—
see "Correspondence")

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Task Group Report

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RADIOACTIVITY
Honma, Greendale, Hahn, Levin, Friedlander, Davis, Kramer, Moeller, Pecsok, Lucas, Ilcewicz, von Buttlar

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Journal

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November 1958

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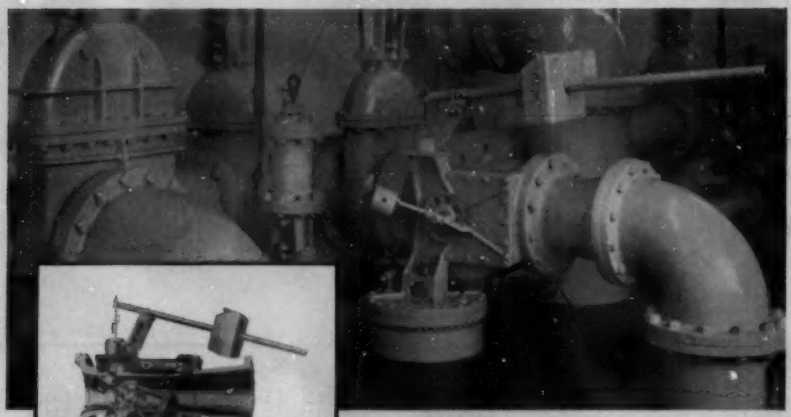

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AWWA SECTIONS

Nov. 5–7—Virginia Section, at Jefferson Hotel, Richmond. Secretary, J. P. Kavanagh, Dist. Mgr., Wallace & Tiernan Inc., 213 Carlton Terrace Bldg., Roanoke.

Nov. 6–7—Intermountain Section, at Newhouse Hotel, Salt Lake City, Utah. Secretary, William C. Hague, Chief Engr., Metropolitan Water Dist. of Salt Lake City, 703 Tribune Bldg., Salt Lake City, Utah.

Nov. 10–12—North Carolina Section, at O. Henry Hotel, Greensboro. Secretary, D. Y. Brannock, Supt., Water & Sewage Plants, Burlington.

Winter-Spring 1959

Jan. 27—New York Section, Midwinter Luncheon Meeting, at Park Sheraton Hotel, New York. Secretary, Kimball Blanchard, 2222 Jackson Ave., Long Island City 1.

Feb. 4–6—Indiana Section, at Sheraton-French Lick Hotel, French Lick. Secretary, Chester H. Canham, State Board of Health, 1330 W. Michigan St., Indinapolis 7.

Mar. 11–13—Illinois Section, at Morrison Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Mar. 19—New England Section, at Statler Hotel, Boston, Mass. Secretary, J. E. Revelle, Dist. Sales Mgr., Chicago Bridge & Iron Co., 201 Devonshire St., Boston 10, Mass.

Apr. 5–8—Southeastern Section, at Wade Hampton Hotel, Columbia, S.C. Secretary, N. M. deJarnette, Engr., Water Quality Div., State Dept. of Public Health, 309 State Office Bldg., Atlanta 3, Ga.

Apr. 8–10—New York Section, at Powers Hotel, Rochester. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 2222 Jackson Ave., Long Island City 1.

Apr. 9–11—Montana Section, at Jordan Hotel, Glendive. Secretary, Arthur W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

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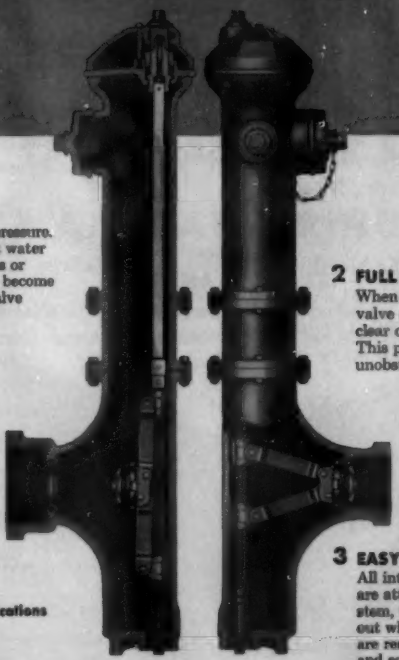
Here is why farsighted city officials install IOWA fire hydrants



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Coming Meetings

(Continued from page 6)

Apr. 15–17—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, Rupert C. Ott Jr., Repr., Neptune Meter Co., 2818—21st St., Columbus.

Apr. 16–18—Arizona Section, at Hi-Way House Hotel, Phoenix. Secretary, Stanford I. Roth, Supvr. of Water Collections, Div. of Water & Sewers, Phoenix.

Apr. 22–24—Kansas Section, at Baker Hotel, Hutchinson. Secretary, Harry W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina.

Apr. 23–25—Pacific Northwest Section, at Vancouver Hotel, Vancouver, B.C. Secretary, Fred D. Jones, W. 2108 Maxwell Ave., Spokane 11, Wash.

May 3–6—Canadian Section, at Queen Elizabeth Hotel, Montreal, Que. Secretary, A. E. Berry, Gen. Mgr. & Chief Engr., Ontario Water Resources Com., Parliament Bldgs., Toronto, Ont.

OTHER ORGANIZATIONS

Nov. 5–7—Water Works Management Short Course, sponsored by Illinois Section of AWWA and Univ. of Illinois, Allerton Park, Ill.

Nov. 17–19—National Fire Protection Assn., Pittsburgh, Pa.

Nov. 18–20—National Conference on Standards, American Standards Assn., Hotel Roosevelt, New York, N.Y.

Nov. 18–20—National Conference on Air Pollution, Sheraton-Park Hotel, Washington, D.C. For information, write: Malcolm C. Hope, Exec. Sec., Natl. Conf. on Air Pollution, Dept. of Health, Education & Welfare, Washington 25, D.C.

Nov. 30–Dec. 5—American Society of Mechanical Engineers, New York, N.Y.

1959

Jan. 19–23—American Institute of Electrical Engineers, New York, N.Y.

Feb. 15–19—American Institute of Mining, Metallurgical & Petroleum Engineers, San Francisco, Calif.

Mar. 1–6—Texas Water & Sewage Works Assn. Short School, Texas A&M College, College Sta., Tex.

Mar. 16–20—National Assn. of Corrosion Engineers, Sherman Hotel, Chicago, Ill.

Mar. 16–20—Western Metal Exposition & Congress, sponsored by American Society for Metals and other technical groups, Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles, Calif. Write: Ray T. Bayless, Asst. Secy., 7301 Euclid Ave., Cleveland 3, Ohio.

Apr. 5–10—5th Nuclear Congress, Public Auditorium, Cleveland, Ohio, including: Nuclear Engineering & Science Conference, sponsored by AWWA and other societies; Atomic Energy Management Conference, sponsored by Atomic Industrial Forum and National Industrial Conference Board; Hot Laboratories & Equipment Conference; and Atomfair, sponsored by Atomic Industrial Forum. Write: T. A. Marshall Jr., Mgr., 1959 Nuclear Congress, c/o Engineers Joint Council, 29 W. 39th St., New York 18, N.Y.

Apr. 6–10—American Welding Society, Sherman Hotel, Chicago, Ill.

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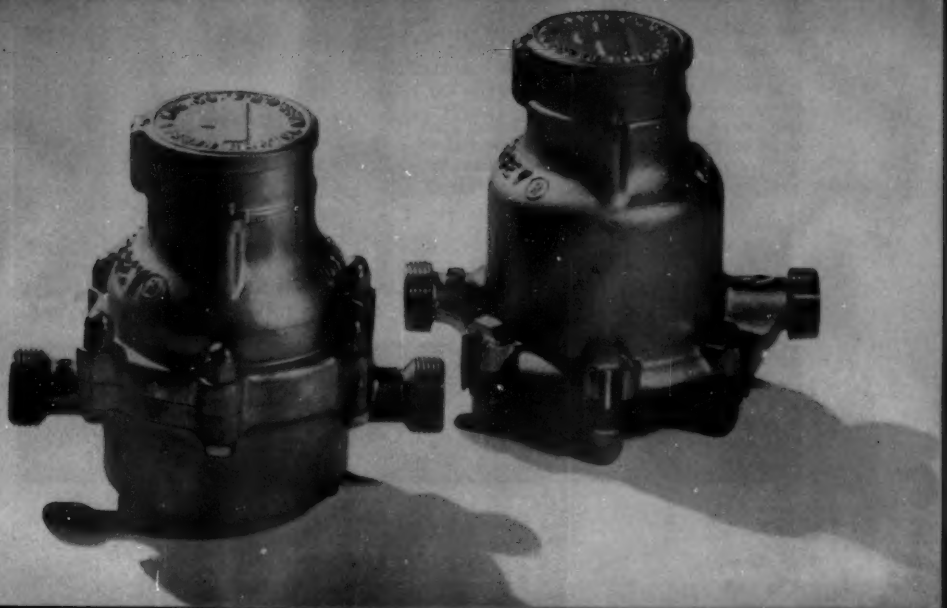

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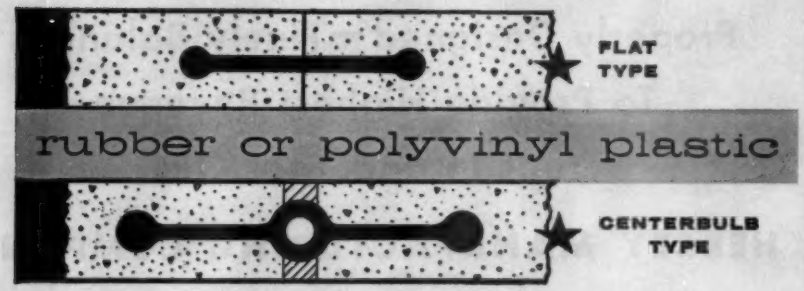
for Watertight Concrete Joints



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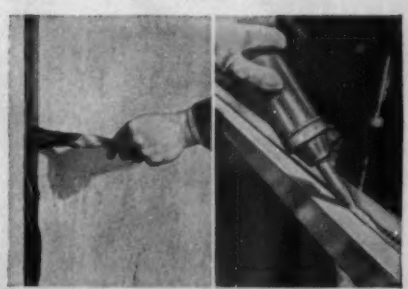

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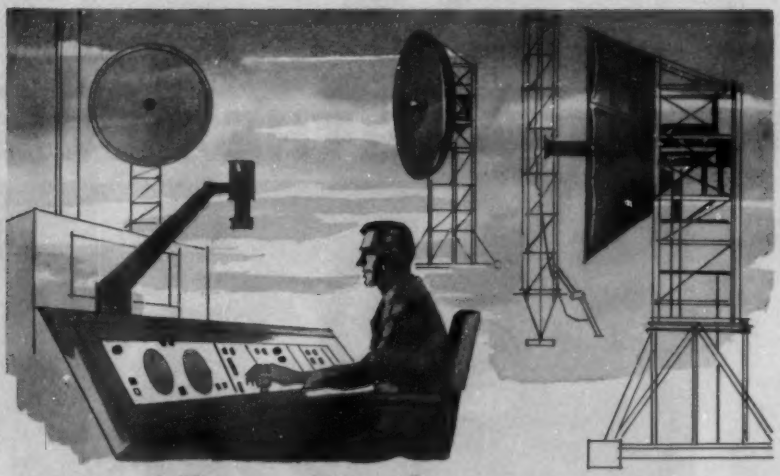


Significance of the DEW LINE

In these days of war and rumors of war, America has just completed one of the greatest construction jobs in history—the 3,000-mile Distant Early Warning Line in the Arctic—called the "DEW" line. It is said to rank with the building of the Pyramids, the Great Wall of China, the Panama Canal, and the Burma Road. Its function is to give early notice to U. S. Military Defense Forces of the approach of enemy aircraft.

There is no way to know, of course, just what might become the U. S. target of enemy planes or intercontinental missiles. But let your imagination picture the result if an enemy could destroy a number of our water works distribution systems. In a short time, the Nation would be paralyzed.

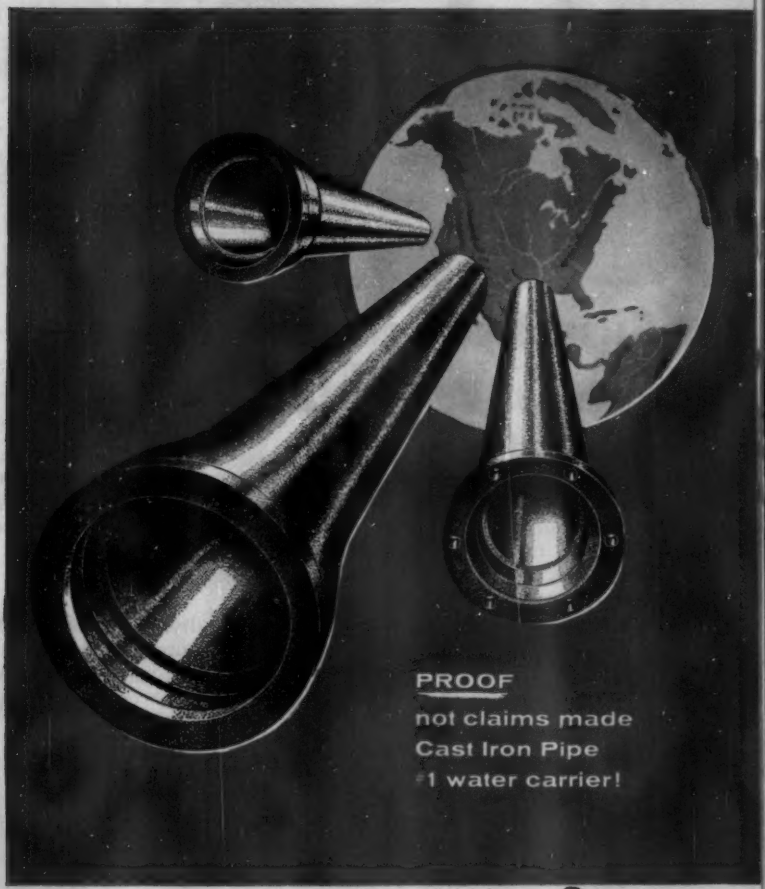
The possibility emphasizes how much the American economy, yea our very civilization, depends upon our modern systems of water distribution. Your water system is buried underground—but don't forget it is there, nor how vital it is to your daily existence.

This Series is an attempt to put into words some appreciation of the water works men of the United States.

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF W WALWORTH

TAKE THE DOUBT



MODERNIZED **cast iron**

OUT OF PIPE BUYING

Specify Modernized Cast Iron Pipe and be SURE!

6 reasons why Cast Iron Pipe is #1 choice of U.S.A.

1. **EXTERNAL LOAD RESISTANCE...**
   6" Class 150 Pipe withstands a crushing load of 17,900 pounds per foot ... nearly 9 tons.
2. **HIGH FLOW CAPACITY...**
   Cement lined cast iron pipe and fittings will not tuberculate ... delivers a full flow for the life of the pipe.
3. **LONG LIFE...**
   42 North American cities are still using cast iron water mains laid 100 years and more ago. Hundreds more have passed the 50 year mark.
4. **BEAM STRENGTH...**
   Cast Iron Pipe is inherently tough ... stands up under heavy traffic load, soil displacement and disturbance.
5. **CORROSION RESISTANCE...**
   Cast Iron Pipe effectively resists corrosion ... vital factor in its long life and dependability.
6. **TIGHT JOINTS...**
   A full range of leak-proof, low cost, easy-to-assemble joints for pipe and fittings are available for all conditions.

Before you choose any pipe remember this important fact ... it will save you many a headache later.

In all the history of water systems no substitute pipe has ever come close to matching cast iron pipe's century old record of dependability, long life and long term economy.

Specify cast iron pipe, and your pipe worries are over, not just beginning. Cast iron's performance is based on PROOF not claims!

THE MAN WHO CHOOSES CAST IRON PIPE TODAY WON'T PAY FOR IT AGAIN TOMORROW!

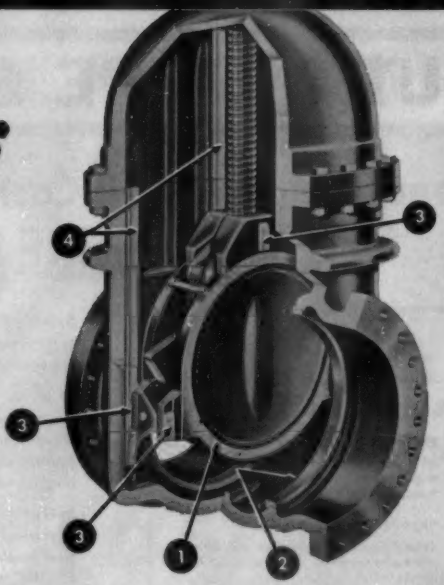
Cast Iron Pipe Research Association
Thos. F. Wolfe, Managing Director
Suite 3440, Prudential Plaza, Chicago 1, Ill.

pipe FOR MODERN WATER WORKS

SMITH THROTTLE CONSTRUCTION VALVES

ELIMINATES
disc tilting and chatter

REDUCES
wear of disc & seat ring faces



Smith Square Bottom Throttle Construction Valves have all of the time-proven design and construction refinements of standard Smith Gate and Tapping Valves and are recommended for severe service applications such as throttling in a partly open position, daily or frequent operation against high unbalanced pressure, high velocity or installation in a flat position in vertical piping.

The design features consisting of disc shoes and body tracks mechanically lift and hold the disc ring face (1) out of contact with the seat ring face (2) at all points of disc travel with the exception of the fully closed position.

Throttle construction valve discs are provided with three non-ferrous metal shoes (3), precision-machined and jig located. Valve bodies are provided with three non-ferrous metal machined tracks (4). The three disc shoes register with the three body tracks and each shoe is in contact with a track while the valve is unseated and in any partially open position. The bottom section of each track is bevelled to insure that the shoes will not bear on the tracks when the valve is fully closed.

This construction prevents damage to and uneven disc and seat face wear and assures long service life under severe operating conditions.

Single throttle construction is used when the flow is not subject to reversal. Double throttle construction when the flow is subject to reversal.

58

THE A.P. SMITH MFG. CO.
EAST ORANGE, NEW JERSEY

EVERY BUSINESS INVOLVED IN PURCHASING FABRICATED STEEL PIPE SHOULD HAVE THIS INFORMATIVE BROCHURE IN ITS FILE!

SEND FOR YOUR FREE COPY . . .
IT MAY SAVE YOU MONEY!

MORGAN THINKS BIG . . . WORKS BIG . . . MAKES YOUR FABRICATION SAVINGS BIG!

If there is such a thing as specialization in the fabrication industry, then Morgan's specialty is that of working in big things — for in this virtually unlimited field, Morgan is peculiarly geared, and therefore able to save you money. For instance, municipalities throughout the country have discovered that Morgan is in a position to provide large diameter fabricated steel pipe lined and coated to meet specifications of American Waterworks Association at a fraction of former cost.

FOR YOUR FREE BROCHURE ON FABRICATING, WRITE:

Morgan Steel Products, Inc.
CUSTOM STEEL FABRICATORS
Working in all types of ferrous alloy . . . [illegible] AND LARGE SIZE PIPE . . . [illegible] . . .
[illegible] . . . CHUTES . . . SMOKESTACKS . . . HOPPERS . . . BREECHINGS . . .
6700 MORGAN AVENUE • CLEVELAND 27, OHIO • Michigan [illegible]

One of two Permutit Automatic Valveless Water Filters at O. M. Scott & Sons Co. Chemical Products Plant, Marysville, Ohio. Each filter is 7' diam. and rated at 116 gpm. The complete Permutit water-treatment system was engineered by H. A. Williams and Associates, Columbus, Ohio.

"No maintenance or operating expense with our PERMUTIT Valveless Filters"

● These filters have been operating continuously for over a year and a half . . . supplying water for process, boiler feed and drinking. They follow a Permutit Precipitator that treats raw well water with lime, soda ash and coagulants. Either filter can handle full

Service Manager, puts it: "Our Per-

coagulants. Either filter can handle full

Service Manager, puts it: "Our Permutit Automatic Valveless Filters are operating very satisfactorily. The filter-bed and underdrain system stay clean with no evidence of blow holes or sifting of filter media to the underdrain system. We now inspect them only twice a year."

● The Valveless Filter is completely automatic—yet costs up to 45% *less* than conventional automatic gravity filters because it uses no expensive valves, flow controllers, pumps or hydraulic or pneumatic control systems.

Send for descriptive bulletin. Address: The Permutit Company, Dept. JA-11, 50 West 44th Street, New York 36, N.Y. or Permutit Company of Canada, Ltd., Toronto 1, Ontario.

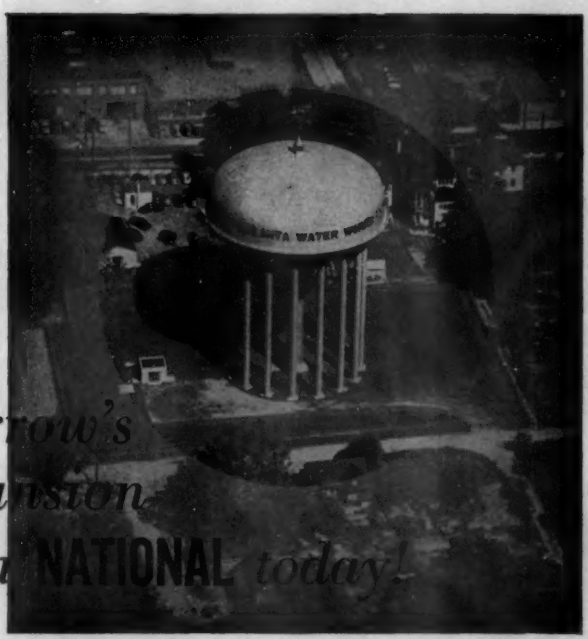
PERMUTIT®

rhymes with "compute it"

A DIVISION OF PFAUDLER PERMUTIT INC.

Water Conditioning

Ion Exchange • Industrial Waste Treatment



For tomorrow's expansion call in NATIONAL *today!*

Like Atlanta, Ga., *you* too can meet tomorrow's increased water demands with *clean water mains*. When the coefficient of sections of Atlanta's 45 year old main dropped to a low of 44, Waterworks General Manager, Paul Weir ordered National cleaning. Results were outstanding. Water pressure and capacity doubled, giving better fire protection and higher water pressure to outlying sections.

Do as other leading cities have done—let *National* cleaning provide for tomorrow's expansion without capital expenditure today! We can prove that National cleaning is an investment—not an expense.

Write us today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafi., Lima, Peru

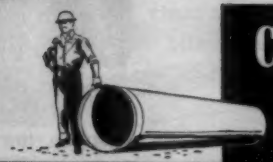
The Swing IS TO CONCRETE PRESSURE PIPE

FOR SEWER FORCE MAINS...

Here are some of the reasons why. Concrete Pressure Pipe not only is virtually permanent itself but also has permanently high carrying capacity. Pumping costs do not tend to rise over the years and lines do not have to be taken out of service for cleaning and scraping.

From an installation standpoint the joints in concrete pressure pipe are simple and easy to make up in the ditch. They are watertight, yet at the same time offer the advantage of enough flexibility to withstand changes in position due to settlement, misalignment or temperature variations.

More and more cities are swinging to concrete pressure pipe for sewer force mains as well as water mains. It will pay you to consider Concrete Pressure Pipe for your installation.



Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 N. LaSalle Street
Chicago 1, Illinois

1879—ROSS—1879

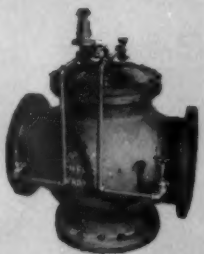
Automatic Valves

ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting

Maintains safe operating pressures for conduits, distribution and pump discharge



SURGE-RELIEF VALVE

REDUCING VALVE

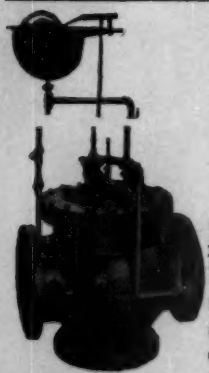
Maintains desired discharge pressure regardless of change in rate of flow

Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.

A self contained unit with three or more automatic controls

COMBINATION VALVE

Combination automatic control both directions through the valve.



FLOAT VALVE

Maintains levels in tank, reservoir or basin

1. As direct acting
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

Electric remote control—solenoid or motor can be furnished

REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

Packing Replacements for all Ross Valves Through Top of Valve

ROSS VALVE MFG. CO., INC., P. O. BOX 593, TROY, N.Y.

Did you hear a lot of customer complaints about low water pressure last summer? After the spring's heavy rains which filled reservoirs to the brim all over the country, *there should be no water shortage.* The problem probably rests underground . . . mains and distribution grids choked by pressure-killing tuberculation and corrosion.

There's one sure cure for your pressure problem . . . the Centriline Process. Centrilining permanently increases carrying capacities in all sizes of pipe by eliminating tuberculation and corrosion forever. After loose scale and tubercules are removed from the pipe, the Centriline machine applies a smooth, uniform coating of cement-mortar to the pipe wall by centrifugal force. Fast and economical, Centrilining is accomplished with a minimum of interruption to surface traffic, since the pipes are lined in place and excavations are not required at laterals and services.

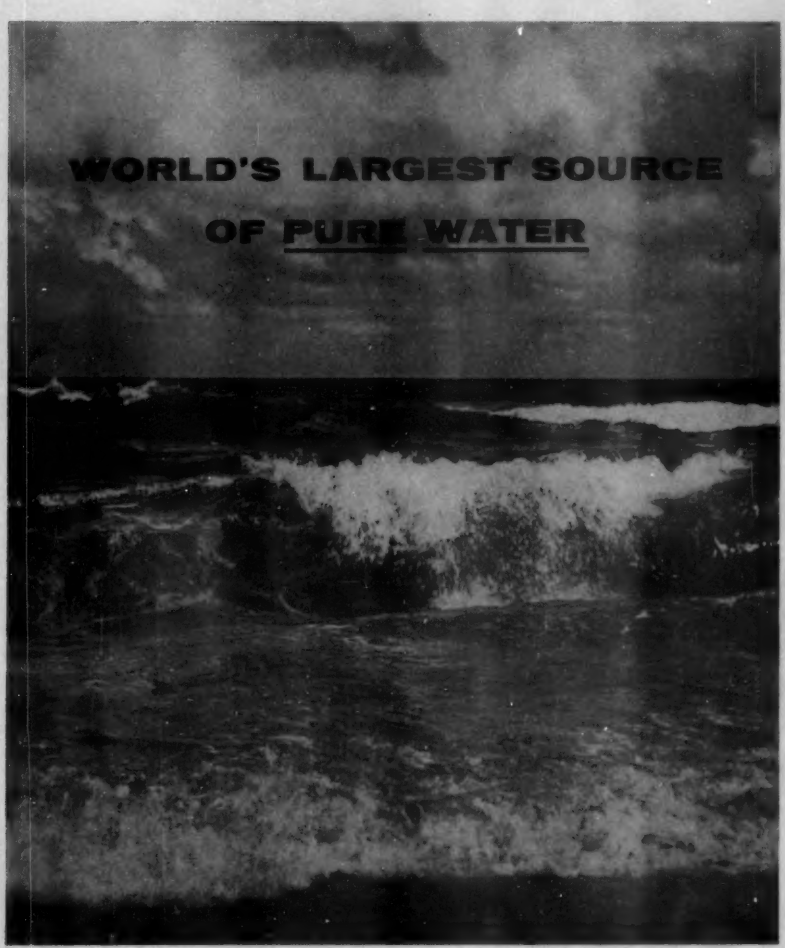
With the introduction this year of the new, small diameter Centriline machine, you can permanently protect all water lines from 4 to 144 inches in diameter. Send today for our new brochure which fully describes the Centriline Process.

CENTRILINE CORPORATION

A Subsidiary of Raymond International Inc.

140 Cedar Street
New York 6, N. Y.
WOrth 2-1429

Branch Offices in Principal Cities of the United States, Canada and Latin America.



The ocean is the only inexhaustible source of water. If you are located near the ocean, Maxim Sea Water Evaporators — proved for years on ships around the world and now in land-based installations — can use this source as the answer to your water supply problem. Whatever your gallonage requirements, Maxim can investigate with you the economics of sea water distillation for your community. Maxim has proved, cost-saving methods. Please write for details.

THE MAXIM SILENCER COMPANY

SUBSIDIARY OF EMHART MANUFACTURING COMPANY

110 HOMESTEAD AVENUE • HARTFORD, CONNECTICUT

MODERN WATER STORAGE at Pueblo, Colorado

750,000 gallon tank on 120 ft tower.
Diameter 62 ft. Head range 35 ft.

Pittsburgh-Des Moines

These fine-appearing PDM Radial Cone Elevated Steel Tanks serving the city of Pueblo typify the value, craftsmanship and dependability inherent in Pittsburgh-Des Moines water storage units of every type. Full information on the various designs, with tables of capacities and numerous photographs, are presented in our 20-page Elevated Tank Brochure. Write for your copy.

1,500,000 gallon capacity tank on 70 ft tower. Diameter 88 ft. Head range 35 ft.

Pittsburgh-Des Moines Steel Company

Plants at PITTSBURGH, BALTIMORE, DES MOINES, SANTA CLARA, FRESNO, and STOCKTON, CAL.

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BALTIMORE (26) ..... Curtis Bay Station

PDM
ELEVATED STEEL TANKS

FLOW COEFFICIENT=155

The ebony-like finish on the inside surface of the steel water pipe shown above is a typical spun lining of Bitumastic 70-B AWWA Enamel. This type of lining has been tested and proved to have the highest flow coefficient available today.

That's one reason why steel pipe, lined with Bitumastic 70-B AWWA Enamel is such a good investment for water lines. Delivery stays high, too, year after year, since this enamel provides the best protection against tuberculation and incrustation known today.

Investigate steel water pipe—lined and coated with Bitumastic 70-B AWWA Enamel—for your next water-supply project.

Koppers Company, Inc., Tar Products Division, Pittsburgh 19, Pa.

KOPPERS

ONLY KOPPERS MAKES

BITUMASTIC

REG. U. S. PAT. OFF.

70-B ENAMEL

USE NORTHERN GRAVEL
for
RAPID SAND FILTER

FILTER SAND SPECIFICATIONS are carefully laid out. The Effective Sizes and Uniformity Coefficients used by Consulting Engineers and also recommended by the American Water Works Association are the result of long years of research and experience.

The Northern Gravel Company is equipped to give you prompt shipment whether it be one bag or many carloads, exact to specification. Filter sand can be furnished with any effective size between .35 MM and 1.20 MM.

CHEMICAL QUALITY of the filter sand is also important. It must be hard, not smooth and free of soluble particles. This requires perfect washing, and grading facilities. We have every modern device for washing, drying, screening and testing.

FILTER GRAVEL supporting the Filter Sand Bed must be, in turn, properly graded to sizes calculated to support the Filter Sand, and be relatively hard, round and resistant to solution.

The new Northeast Station in the City of Detroit, recently completed, is one of the major projects included in the water department's expansion program. The Northern Gravel Company furnished 120 carloads of filtering materials for the 48 rapid sand filters incorporated in this plant.

Northern Gravel has no equal in facilities and our reserves of both sand and gravel are inexhaustible. Northern Gravel Company has been in business over 40 years. We guarantee uniformity of products and our records enable us to duplicate your requirements on short notice. Our location is central and we have commodity rates in every direction.

NORTHERN GRAVEL COMPANY

Muscatine, Iowa

P.O. Box 307 **Phone: Amherst 3-2711**

Installing 48" Pratt High Pressure Rubber Seat Butterfly Valve in a Toledo, Ohio water main. Engineers: City of Toledo Water Department; George Van Darp, Chief Engineer.

TOLEDO... Chooses Pratt Butterfly Valves for Water Mains

Long after this valve is buried, in six months or sixty years, it will still be easily opened or closed by one man using a standard tee-wrench. Pratt Valves are designed to give the kind of honest dependability you need for water main use... the disc edge is corrosion-resistant and seats accurately in a rubber liner made extra-heavy to prevent permanent set. The one-piece stainless steel valve shaft rotates in lifetime lubricated bronze bearings, and the operator is permanently lubricated and sealed to withstand seepage.

In 1956, the City of Toledo purchased 13 Pratt Rubber Seat Butterfly Valves for its water mains, in 24", 30", and 48" diameters. All of them were designed for buried service without protective vaults around valve or operator, **adding substantial savings in installation costs** to their freedom from maintenance problems.

Pratt engineers stand ready to help you select valves for distribution service or any water works application. Call on them with your next valving problem.

Have you sent for your copy? . . . of Pratt's 40 page Manual of Rubber Seat Butterfly Valves. Useful — contains latest pressure drop and flow data, conversion tables, butterfly valve theory and application.
Catalog B-2C.

HENRY PRATT — RUBBER SEAT Butterfly Valves

Henry Pratt Company, 2222 S. Halsted St., Chicago 8, Ill. Representatives in principal cities

WATER FOR U.S. AIR FORCE ACADEMY

29,000 feet of Armco Pipe delivers water across mountainous area

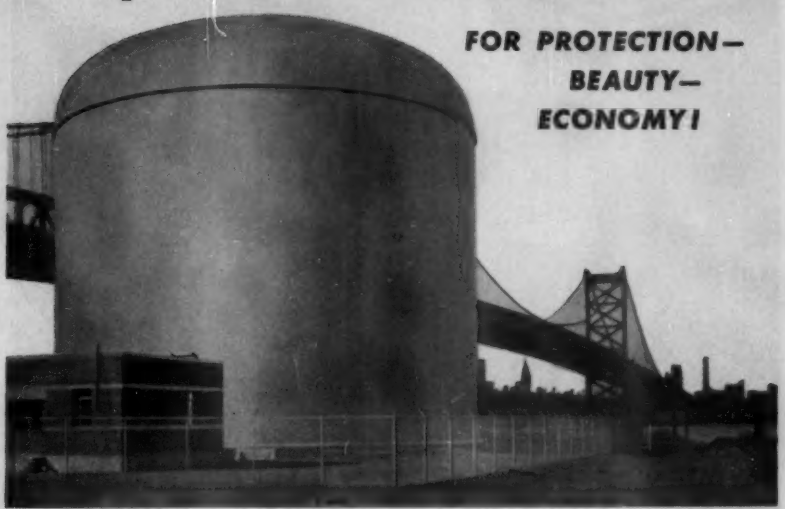
The United States Air Force Academy, like hundreds of American cities, relies on Armco Welded Steel Pipe for water supply lines. Shown here is part of the 29,000 feet of Armco Pipe being installed to carry water from Colorado Springs to the Academy. This water line was laid during the winter over rough mountain terrain. Even so, the job was completed on schedule.

Armco Pipe can help solve *your* water supply problems too. Linings and coatings are supplied according to AWWA Standard C-203. Write us for information related to your particular requirements. Armco Drainage & Metal Products, Inc., 5238 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada: write Guelph, Ontario.

Armco Welded Steel Pipe

ARMCO®

Camden's new 5,000,000-gallon standpipe painted with Inertol®...



• This 5-million-gallon standpipe can look forward to long years of maintenance-free economy, a trim, attractive appearance. Inside and out, it's protected with Inertol paints!

Exterior surfaces are guarded with Inertol's rugged, weather-resistant aluminum paint; interior surfaces, with Inertol's asphaltic tank paint . . . imparts neither taste nor odor to potable water.

Specified by Consulting Engineers Havens & Emerson, New York, these Inertol coatings meet the exacting requirements of water works service. Leading consulting engineers all over the country specify them again and again.

A prominent shipbuilding and manufacturing center, Camden, N. J., is one of many cities which benefit from Inertol coatings. *You*, too, can benefit from Inertol's 50 years' experience in protective-decorative coatings designed to withstand submersion, weather and harsh chemical and abrasive conditions of municipal and industrial service.

Send today, without obligation, for Inertol's "Engineers' Painting Guide" and "Tank Paints"—a handy portfolio of painting ideas. Just write us on your business letterhead, giving your title.

Ask about Rustarmor®, Inertol's new hygroscopically controlled rust-neutralizing paint —excellent for standpipe and water tank exteriors.

Inertol

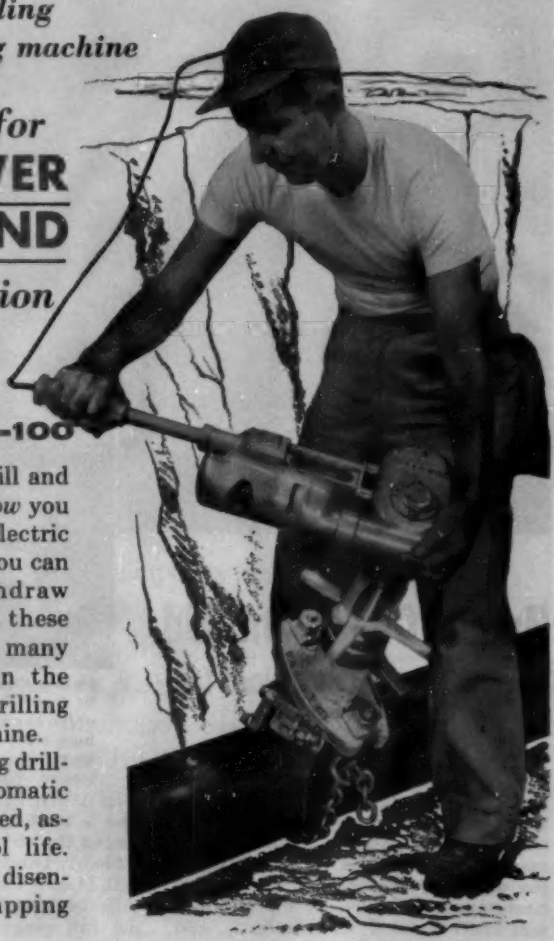
A complete line of quality coatings for sewage, water and industrial wastes plants.

INERTOL CO., INC.

484 Frelinghuysen Avenue, Newark 12, N. J.
270 South Park, San Francisco 7, California

NOW... a drilling and tapping machine

designed for **POWER** *or* **HAND** *operation*



the NEW MUELLER® B-100

Now you can drill and tap with power! *Now* you can choose air or electric drive units. *Now* you can reverse and withdraw under power. Yes, these new features and many more are yours in the Mueller B-100 Drilling and Tapping Machine.

Power feed during drilling operation is automatic — drill is not crowded, assuring longer tool life. Feed yoke, easily disengaged, permits tapping under power.

Ask your Mueller Representative, or write direct for complete information.

MUELLER CO.
DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario.

Hagan Coagulant Aid

proves most economical for Wilkinsburg, Pa., plant

Hagan Coagulant Aids are easy to feed. They can be dry-fed or fed as a solution. The Wilkinsburg plant uses this dry feeder to put Coagulant Aid No. 18 into solution.

The Wilkinsburg-Penn Joint Water Authority plant uses Allegheny river water that is high in manganese. Careful tests established lime, potassium permanganate and alum treatment to be the most effective method for manganese removal. However, the precipitate was finely divided, slow to settle, and carry-over of floc clogged filter beds.

To speed floc settling, the chief chemist tried both activated silica, and, with State Health Department approval, Hagan Coagulant Aid No. 18. Both were given laboratory tests and plant tests of several weeks' duration. At the end of the testing period, it was found that both gave equally good results at comparable chemical costs. However, the fact that Hagan Coagulant Aid could be dry-fed, while the preparation of the activated silica sol was a time-consuming task, made Hagan the obvious choice.

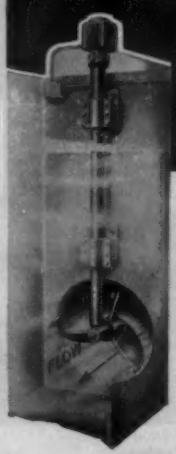
Nearly two years of usage has proved that Hagan Coagulant Aid works well with the other treatment chemicals over the full range of fluctuation in raw water characteristics. These Aids are non-toxic, easy to handle and feed, and produce a large tough floc that speeds settling time and reduces carry-over.

Write for Bulletin 410-12-2 for information on the complete line of Hagan Coagulant Aids.

CALGON COMPANY

DIVISION OF **HAGAN** CHEMICALS & CONTROLS, INC.
HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
DIVISIONS: CALGON COMPANY, HALL LABORATORIES
IN CANADA: HAGAN CORPORATION (CANADA) LIMITED, TORONTO

When measuring through the discharge end of a submerged throat or conduit, DEPEND ON . . .



10" to 72"

Sparling
WATER WORKS INTAKE METERS

Sparling Water Works Intake Meters are designed to provide efficient and economical service. Ideal for a large volume of water flowing through the discharge end of a submerged throat or conduit. The very simplicity and variety of models available permit wide application . . . often using the existing headwalls or supports. Propellers may be plastic or stainless depending upon installation and use. Maintenance is simple. Available with Sparling's new Indicator-Totalizer 245. Drop pipes can be any length. Ideal for use in telemetering systems. 10" to 72"

OTHER OFFICES:
Atlanta 3 • Chicago 4
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Denver 6 • Kansas City 6, Mo.
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☐ Yes! We are interested in increasing our metering efficiency. Send us more information . . . no obligation, of course.

☐ Also send information on Sparling's line of Water Control Equipment.

Name _____

Company _____

Address _____

City _____ Zone ____ State _____

Send to: Dept. JA-11,
SPARLING METER COMPANY
225 N. Temple City Blvd.
El Monte, Calif.

When you plan your new facilities, include W & T Equipment, both Chlorinators and Dry Chemical Feeders.

"... this is where we plan to put the W & T Dry Chemical Feeders."

When you plan your new plant or the expansion of your present one, be sure to plan a place for W & T Dry Chemical Feeders as well as Chlorinators. W & T Feeders are used for every type of dry feeding problem found in water and sewage treatment plants.

W & T makes both volumetric (volume measurement) and gravimetric (weight measurement) feeders. There is a feeder for any size job, from small equipment to measure out ounces, to accurate giants capable of handling thousands of pounds per minute.

To find out more about W & T Dry Chemical Feeders, write for bulletin S-124. Or let us know the type of feeder problem you have, so we may send publications describing the W & T equipment best suited for your job.

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 50 • NOVEMBER 1958 • NO. 11

Meter Records in System Planning

Panel Discussion

A panel discussion presented on Apr. 24, 1958, at the Annual Conference, Dallas, Tex.

Dallas—Henry J. Graeser Jr.

A paper presented by Henry J. Graeser, Jr., Supt., City Water Works, Dallas, Tex.

PROPER records are essential to the proper management of any business. Business in general, since the close of World War II, has experienced startling changes in methods of collecting and using information. Certainly, it is of no advantage to collect information that is not to be used. With unemployment in excess of 5,000,000 as of the middle of March 1958, and with conflicting opinions as to whether the current "recession" will soon end, or extend into 1959 and beyond, it is certain that management throughout the business world is trying properly to utilize information available to determine future actions. Utility managers and executives should be no less conscious of the necessity for using any available information in planning current operations or future expansions.

Punch Card Records

The author would like to point out some of the fundamentals of machine records that utilize the punch card system—what the machines will do and how they are used. The key to an effective meter-billing system is a good filing system. Filing can be done manually, but if the data and number of items are large, then it is natural to look for a less painful and more inexpensive method to sort and file data.

Dallas began by using a punch card system under the central control of the city auditor. There are a number of firms offering equivalent equipment and systems. In addition to billing water and sewer accounts and handling store accounts, the same equipment is used to handle the tax bills, corporation court tickets, and, incidentally, to keep a name record of the number of traffic

violations so that a violator can be quickly screened to see if he has jumped any tickets. Payroll accounting is also handled on the computer. In addition, each division receives a coded monthly statement of its budget position by account. Although the machines themselves do nothing unusual, what they do they do rapidly. The functions of the machines are reading, checking, coding, duplicating, filing, arranging, sorting, posting, copying, searching, pairing, counting, computing, listing, summarizing, and printing. All of these thirteen operations can be done manually as well. Therefore, any business considering a new billing method should be guided by the size and number of accounts to be billed and the volume of transactions to be handled. If the work can really be done more cheaply with less expensive and more modest equipment, one ought to beware of spending money for unnecessary punch card machinery. There is no doubt that these machines have tremendous appeal, but there are areas where an electric typewriter and hand billing are much cheaper and more rapid than punch card equipment. For example, work study has shown that a clerk-typist with an electric typewriter can issue a final bill more quickly and cheaply.

The magic of the machines sometimes leads one to wonder if they will not eventually become the masters, rather than the servants, of men. It is important to note that even the newest and most amazing electronic machines can provide no answers until factors and information have been properly fed to them. This fact has given rise to the entirely new profession of programing. A programer has to know both the machines and the manual solution of the problem thoroughly before he can intelligently "program" the machine. In experimenting with some of the work done at Dallas, the machine has sometimes been completely stumped despite its speed, simply because it was not programed correctly.

Another factor that is well worth considering is the reluctance of people to depart from older methods. Punched-card data sheets are often bewildering when first seen by someone unused to them. For this reason a thorough training program is essential before a punch card system of machine records is adopted. Employees must become competent to use new media and must develop confidence in the data they receive. Technical people must also be convinced that the machine is dependable, gives the proper results, and allows flexibility in final computation. The author speaks from experience, because the too rapid implementation of new procedures using electronic computers resulted in confusion in Dallas. Expensive as it is, it is still felt that maintaining the old method beside the new one, where practicable, is a good, safe course.

Coding of Punch Cards

Each city, because of the peculiarities of its own system, will want to vary the type of information and the method with which it is extracted from the punch cards. The Dallas water department records on each customer are designed to be used both by the engineer and the meter-reading department. These same cards are also available for customer inquiry and are used by the clerks in the office. Meter-read data are made available in a convenient form so that each clerk has a complete history of the customer available when a complaint is received. This helps to avoid delays and long searches for

information. Complaint clerks have punch cards that record the last complaint made by the customer, the solution of the complaint, the history of the account, and how much water has been used for several years back. All of this information is consolidated on four small punch cards, three of which are in the tub file next to where the clerk is seated.

The secondary information provided by the primary records will become apparent if the information obtainable from this one record is itemized. On the read card there are an occupancy code, account number, the customer's name, a space for correction factors for either demand rates or special rates for a certain time of the year, the class rate, service address, meter location, meter size, compound meter designation, applicable minimum, the two previous meter readings, reading sequence. On each card there are 80 fields. These cards can be sorted according to each of the fields into which information can be punched. These punching fields, of course, can be divided according to particular needs. Once this information is on the card, then all the accounts can be sorted for any listing of information at a rate of about 1,000 cards per minute, which is quite rapid handling. For example, if one wishes to locate all of the 2-in. meters in a particular district, this information can be obtained very simply by sorting the cards for this particular field. The occupancy code * is another handy bit of information for determining who really pays for the water. This type of information is most helpful in a rate study or in determining minimum charges, because monthly variations in consumption can be determined for every designated type of customer.

The *account number* is used, of course, for control purposes, although there is another novel use for it. Before the read books are given to the meter readers, the folios, or last four digits of each account number, are totaled. When the book is returned after the meters have been read, the same numbers are immediately totaled again. Thus, if a card is lost, it is possible to determine which account it controls and to bring it to the attention of the reader concerned. One day soon after the Dallas water department began using this count, a card was lost and the reader went back and found it beside the meter. Needless to say, this method of counting has convinced readers it will do them no good to "lose" any of their cards.

The *customer name* is shown if the account is active, whereas an inactive meter is indicated by an orange card. It can be told at any time how many of the meters that have been set are serving active accounts and how many of them are temporarily inactive.

The columns designated *correction factor* were formerly used when special summer rates were established. Plans are being made to correlate read books with census tract designations as soon as possible. Once this is done, it will make possible comparison of water usage and other factors with information secured from the 1960 census.

The rate column may have any one of the following designations: inside city, water and sewer; inside city, without sewer; outside city, water and sewer; outside city, without sewer; inside city, sewer only; outside city, sewer only.

Monthly and annual summaries, as well as summaries by consumption

* For an explanation of Dallas occupancy code designations, see Table 1 of the author's previous paper (*1*).

blocks, are made for each of the above designations as accounts are billed. In other words, it is possible to determine how many customers fall in each rate segment and where they fall according to consumption blocks (1,000-gal blocks). It is easy to see how important such information could be in making a rate study. One could apply a given rate and establish fairly accurately what the proposed rate would yield.

By using a *service address* field, meter cards can be matched or collated against the master cards, also maintained by service address, to make certain that each meter is read according to the previous setting. This is another control field, like the account number field.

The *meter location* field is, of course, of primary benefit to the reader in locating the meter to be read, although it would be fairly easy to run a summary of meter locations by sorting on these columns. By doing so, it could be determined, for example, just what percentage of the meters were in alleys, which particular meters they were, and the addresses they served.

Meter size is of major importance to any water utility. The alarming increase in the number of yard-sprinkling meters is making itself felt on summer days, but by keeping separate accounts, data files can be built by which minimums can be apportioned equitably. Again, a summary of all large meters can be secured by machine at any time, and the total consumption used through them in a given period can be determined by class of consumer.

It is also possible to sort accounts and list them according to different *minimums*. For instance, a 12-unit apartment house carries a $16.20 monthly minimum, and if information were desired as to whether it was fair, or if it were challenged, all such units could be pulled and listed.

The inclusion of the *two previous meter read* data on the card has some additional values which are being found more and more useful. Its primary purpose is to allow the meter reader to check himself to see if his present reading shows a wide variation with previous readings. The read card contains check areas in order that the meter reader may order the meter removed or investigated if he thinks it is necessary. A comparison of consumption data with the previous month, immediately before blling by office clerks, gives valuable information as to when meters should be changed because of underregistration or overreads.

On a trial basis, the Dallas water department deleted one of the previous readings for the purpose of punching into the card the January base consumption for the account. The following January it is planned to scan these cards again. The machine will record all accounts where the consumption the following January is less than a set percentage of the previous January. This particular experiment may lead nowhere at all, but it does illustrate the type of investigation available inexpensively with the punch-card system. It costs very little more to obtain the data, because it is already in the cards. Thus one can do experimenting which otherwise would be prohibitive in cost. Actually, in one Dallas district containing 7,672 meters, comparison was made between December 1957 consumption and January 1958 consumption and it was found that 5,486 accounts equaled or exceeded the previous month's consumption. The remaining

accounts were grouped as follows in relation to the December consumption:

Per cent December Consumption	No. of Accounts
90–99	632
85–89	303
80–84	265
75–79	186
70–74	111
65–69	97
60–64	65
55–59	65
50–54	53
40–49	56
30–39	56
20–29	42
00–19	255

In the group where consumption in January was 00–29 per cent of the December consumption (indicating a drop of 71–100 per cent), a search of the records revealed that 232 of the 297 meters in this group had occupancy changes or discontinuations, which explained the reduction. The remaining 65 were pulled and tested. Of this group, ten of the meters, or 15.4 per cent, were slow and underregistering, but 55, or 84.6 per cent, were accurate at 0.5 gpm and above. This preliminary study indicated that a review of reading data in the office is not as valuable as was hoped at first. It costs very little to search for other areas where consumption changes might give a sense of direction to a meter maintenance program, however. Detecting slow meters, for example, is a real money saver. It might be considered the first line of defense in meter maintenance, particularly because it does away with the necessity for a blanket change-out period.

Computer Analysis

Up to this point the discussion has covered mostly the statistical information available with the normal billing-machine equipment. Dallas is presently considering the rental of a much larger unit to handle all of the city's business and allow direct transfer of the information from the card onto a bill, thus reducing greatly the machine time required for producing the water bill. This machine will also be used for some engineering problems.

Unless there is a large enough amount of work to justify the use of expensive equipment, it is much better to use the numerous new service bureaus available. These new firms are computation services. Their purpose is not to sell computers but to use them in solving problems for others. Their services are almost as valuable to an engineer who knows nothing about machines as they are to one who has been familiar with them for years. The engineer who understands the technical side of his problem can explain it to the computation service expert. He, in turn, generally has the necessary skills in mathematics and computer techniques to solve a working program. It goes without saying that here, again, maintaining the old method along with the new is a pretty good idea until the system is perfected.

In some recent work with the Hardy Cross method of hydraulic analysis it was found that a solution to a particular problem was necessary before a general procedure could be found that would give accurate results. When the machine finally checked the results of the manual computation, it could be established that the procedure would work for larger problems where a solution had not been made. The Dallas work in this field has been directed at setting up a master water system for 1980. Only the major ele-

ments of transmission and supply have been considered in this study, because these are more or less fixed problems. By running 1980 demands against its present system, Dallas has determined, using the Hardy Cross analysis, a series of loops, coefficients, and flows that can be expected on the basis of the estimated load centers of demands. By taking present, estimated demands on the basis of meter reads by areas, and using the same load centers as the master plan, and at the same time omitting certain lines or elements which are not yet built, pressure conditions can be simulated and construction programed as required by growth. It is not necessary to change the loops in this type of analysis, but merely to assign infinite resistance to the line, leaving the loops exactly as they are in the master system. It is planned to use meter reading data according to read districts and census tracts as time goes along, and to use the same load centers as those of the 1980 master plan to determine whether or not pressures will be low in a certain area and what areas should be given priority in construction as growth continues.

There has also been some consideration of the refill problem in the major reservoirs utilized for peak summer periods. Dallas will soon have three filtration plants and six major ground storage reservoirs (16–25 mil gal) on the system. It is very likely that the computer can solve for the most economical pump operation against the refill problem. Where there is a large system with numerous input and refill points at varying locations and distances from the central input, balancing the flows becomes especially difficult when the load has been extreme in one area of the city and light in another. The Dallas area often has localized thunderstorms, that is, it may rain heavily in the southern part of town and none at all in the north, and the loads are vastly different. As a result, the reservoirs are often out of phase, one reservoir being nearly full and another nearly empty. Normal refill procedures will overflow some reservoirs before the others fill. This brings about a very difficult problem of balance. There are often situations where a quick analysis of the distribution system could determine what restrictions or valving could give the most advantageous balance to the system. If this problem were programed on computers, an operating engineer could have his refill operation started in less than an hour in a major service area.

Dallas has also been doing some very interesting research work in connection with maximum day loads. In this study a problem was set up to solve for the significant factors in maximum-day consumption. The major factors were, of course, the number of domestic meters, the humidity, the number of days prior to the maximum day over 100°F, the number of weeks since the last half-inch of rainfall, the maximum temperature on the date of maximum consumption, the number of weeks since March 21, and the time in years since 1946, which was taken as the base consumption year. For observation points, peak- and high-consumption days in June, July, and August from 1946 to the present were used, giving a total of 38 sets of data. Of these, it was found that the only significant factors in the maximum-day water consumption evidently were the total number of installed meters, the previous number of days over 100°F, and the number of weeks since an inch or more of rain had fallen in a single

week. Relative humidity also had some significance. Strangely enough, the maximum temperature on the date of maximum consumption did not seem to be too significant. Seemingly, all maximum days occur over 100°F, and there is not a great deal of difference in the range 103–107°, other factors being the same.

Dallas is considering carrying this investigation further to estimate annual production on the basis of normal growth in meter services, and considering the effect, frequency, and intensity of rainfall especially during the months of June through September. A small rain at weekly intervals during the summer can have a devastating effect on water consumption and income.

These studies have also provided some rather interesting data for estimating future consumption based on [1] average heat and drought conditions, and [2] maximum heat and drought conditions.

The problem of impounding-reservoir yield lends itself well to computer analysis. A recent study demonstrated how a mass of data could be processed quickly by machine. The first test that was reported concerned eight potential reservoir sites on a river system involving some 17,000 sq mi of watershed. With the computer's high speed, it was possible to consider various reservoir sizes under conditions of maximum drought and maximum flood. The machine ran the necessary data in about 4 days, compared to what would have been 9–12 months by normal methods. Also, more computations could be made than by the manual method. Either card input or tape input computers can be used on small projects for a large number of computations. It is possible, for example, to compute information about the yield of a reservoir site, such as what the dependable yield will be: [1] if the reservoir is constructed to have any given capacity, [2] after the initial capacity is decreased by siltation, [3] if a given amount of water is kept in storage as a safety factor, [4] if it can be increased by successive additions to the reservoir capacity, [5] if there is a more severe drought than has ever previously occurred on the reservoir site. This latter point is of particular interest to the operating water manager. It is always possible to have a worse drought than has occurred before. One often wonders what would happen if the total rainfall were so spaced as to result in little runoff. Typical of this type of rainfall would be an inch of rainfall on a dry watershed, which would produce little or no runoff, as is true in many parts of Texas. With even normal rainfall then there can be combinations of occurrences and intensity that are important factors in determining a safe yield. Again, with the electronic computers, an almost unlimited number of hypothetical conditions can be run against a reservoir.

Conclusion

It would be improper to close this discussion without warning that one can compile much useless data. The National Records Management Council has conducted research and installed record control programs in numerous industrial companies and government agencies throughout the country. Research in these installations has indicated that 65 per cent of all records could either be destroyed or transferred to low-cost storage. The cost of existing filing equipment alone is estimated at considerably over $140,000,000. Utilizing information contained in records is therefore no small,

inconsequential matter. It is important to study carefully the type of data being stored and just how much of this information is going to be useful.

The punch card system and its summarizing data do offer a means of compiling a lot of information in a relatively small space. As a matter of fact, through the use of service agencies, investigations are underway as to the possibility of putting much of the punch card information on tape, instead of keeping the cards themselves in bulky storage cabinets. Through the punch card system, however, a great deal of information can be stored, sorted, and referred to in a variety of ways. Nevertheless, it takes careful study by each particular utility as to whether it can afford the expense required to use this system. One must look at these very desirable data as secondary advantages, most valuable to be sure, but the primary considerations are the billing and accounting operations. Generally speaking, it is on the basis of the economy in performing these operations that the project must be evaluated. As an engineer, and one who has used the punch card system in utility management and operation, the author can only speak in very glowing terms of the advantages of having at one's fingertips the wide variety of information supplied by this method of accounting.

Reference

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Meter Records at San Antonio—*R. B. Raw*

A paper presented by R. B. Raw, Director, Customer Service Dept., City Water Board, San Antonio, Tex.

Meter readings, for the most part, are used to measure consumption and render water bills to customers. Although this is the fundamental use of meter readings, a great deal more information can be derived from them. By grouping data from meter readings in significant ways, it is possible to solve many of the problems that arise in the operation of a water utility. This discussion will begin with the meter reading right after it is brought in by the meter reader.

Meter readers of San Antonio write up work orders on conditions they find that indicate faulty operation. If a meter is not registering, or if there is a meter leak, a service leak, or a main break, it is reported on a card, which is turned over to the distribution department.

Recording of Information

The route cards are taken to the machine room and are counted to be sure the meter reader did not lose one. After the cards have been counted, they are sent to a reproducing machine, and all the information from the route card is reproduced on a billing card. This billing card contains the route number, tap number, service level, size of the meter, the census tract, and three readings—the present and two previous readings. These three meter readings are read into an electronic calculator, which computes the present month's consumption and

the last month's consumption and multiplies the smaller figure by a previously determined correction factor. If the product of this multiplication is smaller than the larger consumption, the machine eliminates the card. This card is then turned back to the reading review section, which investigates why the present month's consumption was excessively smaller or greater than the previous month's consumption. The billing cards then have the consumption punched into them. This information is read into the calculator, multiplied by a rate schedule, and the bill is figured. This is all done automatically by a machine that is capable of making 6,000 arithmetical calculations per minute.

The billing card—containing meter readings, consumption figures, and the amount of the bill—is fed into another machine, which reads the holes in the card and prints the figures on the water bill. Every time there is a change in a service level, census tract, or meter size, a machine will punch a summary card, used for printing reports, and based on these classifications. The billing card is passed through a reproducing punch, and the holes in the billing card, representing consumption, are reproduced on the statistical card. Thus, a card is available for every service that can be machine processed.

This basic statistical card is kept indefinitely, and contains the consumption for every month of the year. Thus, officials will for example, 10 years from now, be able to say how many ¾-in. meters used 300 cu ft of water in Census Tract 34, on Service Level 2, during the month of July 1957. Any question of this nature that might be asked in the future can be answered from these cards quickly and economically.

The information from these readings is necessary to supplement information obtained in other areas. Some of the other information obtained in San Antonio that ties in with the meter-reading data is information concerning the time and locality of main breaks. This is, in turn, tied in with information on resistivity of the soil. Of course, all of the data are gathered to prevent the loss of water in the distribution system. It would be desirable to be able to sell 100 per cent of the water that is pumped, but this is impossible, because of all the things that can happen to that water from the time it leaves the well until it comes out of the customers' faucets.

Classification of Data

Meter readings are accumulated in special groups. The first classification is by census tract, which is a fixed geographical area. Meter information by census tract is correlated with other data on population growth (also by the same census tract) to give an idea about where future problems of supply and distribution will be.

The next advantage of accurate meter readings is that accounts may be classified by meter size in consumption brackets. This is important to know and have available whenever a rate study needs to be made. With the proper accounting equipment, the information by meter size can be multiplied by a new rate to find out exactly how much money a higher rate would bring in.

The classification by meter size in consumption brackets also assists in determining proper meter size. For example, in a cycle of 6,000 accounts,

if there are any ⅝-in. meters using over 50,000 cu ft in a month, officials can be sure that no matter how effective a meter maintenance program they have, maintenance people cannot keep the small meters accurate with this much water passing through them every month. Data are available on both extremes in meter registration, thus indicating also how many large meters are registering extremely small amounts of water.

In a city the size of San Antonio, any method that can break down and pinpoint areas where there is a problem tends to reduce the problems of a big city to those of a little one. This is accomplished in San Antonio by dividing the city into service levels, which are a result of the differences of altitude within the city. The production department furnishes information as to how much water is pumped in each one of these service levels. The meter readings are classified by service levels in order to make a comparison of metered production and metered consumption.

In one service level, 9 per cent of the water is lost, and in another service level, 18 per cent is lost. In San Antonio, the average water loss has been cut to 13 per cent, but there is a great deal of difference between service levels. In an effort to pinpoint the water loss problem, officials try to have all water meters accurate through a preventive maintenance program and set up a formal main replacement program in the areas where there are low soil resistivities and numerous main breaks. Both these programs are emphasized in those service levels that have the largest difference between metered consumption and metered production. By fighting the water loss problem by as many different approaches as possible, officials believe that it is just a matter of time until the water loss is reduced to less than 10 per cent on the average. In one of the service levels, this has already been accomplished.

Meter Records at Austin—*Albert R. Davis*

A paper presented by Albert R. Davis, Director, Water & Sewer Dept., Austin, Tex.

The old saying that the water meter is the cash register of the water utility still holds true. Today, however, meter records are important aids in system planning as well. This has long been recognized by the water department in Austin.

In Austin there are three types of meters to be considered: [1] meters at the supply source, including treatment plant, wells, pumping plant, elevated reservoirs, and master meters, which record the water going from the plant to the distribution system; [2] pitot tube and pressure gages; [3] customers' meters. What records or information are needed as aids in planning? First, the amount of water produced and delivered to the distribution system must be known. Second, there must be special information from the distribution system, such as the coefficients of pipes. Finally, it must be known where and when the water is used in the system and what happens to the pressure. All of this information is obtainable from operational records.

Austin's water treatment and pumping-plant records are quite voluminous, but they produce the basic information necessary in the analysis of the water consumption characteristics of the city. Pertinent information is summarized daily in the form of a daily report. Especially important for planning purposes are the usage data, which give total usage in gallons, and maximum-hour and minimum-hour usage rates, expressed in millions of gallons per day. The minimum usage rate is a good aid in daily operation for checking the condition of the distribution system. Any sudden jump in this rate would indicate a bad, undiscovered leak.

A monthly compilation of the usage and usage rates is a part of Austin's routine record keeping. From this record such basic information as annual average day, maximum day, and maximum hourly rates can easily be obtained.

Pitot tubes or meters fill an important niche in the meter record. The pitot tube is used in making special tests or investigations, such as leak surveys, or to determine the coefficient of roughness on the inside of water mains where installation of a permanent meter would not be economical. Recording pressure gages are well distributed over the entire system. Fire stations usually offer a good location for housing the instrument, which at the same time provides the fire department with pressure information.

Generally one thinks of a customer's meter as a means of measuring the service given by the water utility to the customer. When the bill has been rendered and paid, there is still a very important use for the information recorded on it. Austin is using a machine billing system, but every utility does not need to have computer equipment to get the information, although it helps.

The meter reader's book, or meter route, is the basic tool for compiling the necessary data. Each meter book is summarized as it is billed. At the end of the billing period, all of the summary cards go through the machine and monthly totals are taken for the entire town. This information goes into the financial and accounting reports.

In Austin's system of account records, one additional step has been worked out in the compiling of information from the meter book summary cards. This step gives the following four pieces of information for each meter book: [1] the number of vacant accounts; [2] the total number of active accounts billed; [3] the total gallons billed; and [4] the revenue.

In 1928 Austin was divided into nine hydraulic-survey districts for the purpose of making leak surveys. In 1944 the city began recording the gallons billed in each survey district. With the addition of computer equipment in 1953, the recording was begun in its present form. In 1951 the number of districts was increased to 29, and at present (1958) there are 40 districts.

Each meter book is assigned to a survey district and the district number is punched in the summary card. Hydraulic survey districts are not the only good way to divide the area. It just happened that Austin had the survey districts and that this offered an opportunity for collecting and keeping the records of water billed in that area. At the end of billing period all of the meter book summary cards are sorted and run through the machine, which gives a tabulated report for each

district. The operator estimates that the time required to compile this report is 30 min.

Over the years it has been interesting to observe what happens in the various districts. The variation in water consumption is quite revealing. In one particular district the actual consumption during a 5-year period was smaller by 16 per cent. In another district, over the same period, the consumption increased 210 per cent. The amount of rainfall is also reflected in the consumption figures. Economic trends can be detected, but not anticipated, by consumption data. In Austin it has been found helpful to tabulate each survey district on a separate sheet using years on the vertical and months on the horizontal scales. The facts disclosed by these studies are useful in working out a time schedule for capital improvements. If a particular area is not growing, the amount of improvement planned for that area may be deferred and the money spent in an area that needs more than the amount planned for it.

TABLE 1

District No. 16 Usage, 1956

Item	Usage *gal*
Annual average day	33,000,000
Maximum day	64,714,000
Maximum hour	114,800,000
July 1956	1,728,571,000

It may be asked how this information can be used as a basis for planning. First, from the plant records the total amount of water delivered in a year to the distribution system is known, and that, divided by the days in the year, gives the annual average day. The maximum day and maximum hour come directly from the records. From plant records and customer records one determines the unaccountable or line losses. From the survey districts one can tell where the water was used, and, from pressure-recording charts, what happened to the pressure.

The 1956 figures for district No. 16 (Table 1) showed that 38,763,700 gal was billed for July. Considering this to be only 90 per cent of the actual consumption (the other 10 per cent being accountable to average line loss), the actual July consumption would be 43,071,000 gal, or 1,389,000 gpd. The maximum day for July, citywide, was 64,714,000 gal. Multiplying by 31 (number of days), and dividing by the total usage in July, gives

$$\frac{64{,}714{,}000 \times 31}{1{,}728{,}571{,}000} = 1.16$$

or 116 per cent actual citywide usage, which is what the system would have to supply if all days in July equaled the maximum day. If it is assumed that this percentage is valid for all parts of the system (it could be more or less in any one district), the hypothetical maximum day for district No. 16 would be this percentage of its average day, or

$$1.16 \times 1{,}389{,}000 = 1{,}611{,}000 \text{ gal.}$$

Dividing the maximum hour (citywide) by the maximum day gives the latter in percentage of maximum day, or

$$\frac{114{,}800{,}000}{64{,}714{,}000} = 1.77$$

or 177 per cent. This percentage of the maximum day for district No. 16 gives

$$1.77 \times 1{,}611{,}000 = 2{,}850{,}000 \text{ gal}$$

for the district's hypothetical maximum hour.

Briefly, then, the mains supplying this district must be able to carry 2,850,000 gal at the peak hour while the other 28 districts are all being supplied. Similar information can be calculated and tabulated for each of the other districts.

The next problem is to prepare a distribution map showing the trunk mains in the system, usually 12 in. and larger. In some cases an equivalent line size may replace two or more smaller lines in order to simplify a complex piping layout. The quantities delivered to each takeoff point are tabulated from each hydraulic survey district. There are too many intricate details in this preparation to spell out in this article, and it should be sufficient to say that the records have supplied the basic facts from which to proceed. With the information on the map it is then possible to proceed with Hardy Cross calculations by slide rule, digital computer, or any other method.

The Austin distribution system is set up on a trunk main map with the quantities indicated ready for the first step in planning and an analysis of the existing system at the maximum hours. Next a trunk main map needs to be prepared showing what happens during off-peak hours, when the supply of water must be replenished in the elevated storage reservoirs. These quantities are also available from the plant and reservoir records.

The next step is to look into the future, preferably from the population viewpoint. Austin has a population of 200,000 now, and it is reasonable to anticipate 500,000 within the foreseeable future. The city planning department has developed a tentative plan outlining major area developments, which offer some indication of where future growth will be. With this as a starting point, the engineers have laid out a plan for treatment plants, distribution system, and elevated reservoirs.

The trunk mains have been calculated and placed on a proposed trunk main map comparable to the one used in analyzing the present system, and the Hardy Cross analysis applied. Strangely enough, the problem of replenishing elevated storage, rather than that of maximum-hour demand, became the critical one in the design of certain portions of the system.

Austin experience shows that records are an absolutely essential part of all operational procedures. The extra bit of time and money required to keep adequate records is a good and justifiable expenditure.

Study of Domestic Water Use

Task Group Report

A report of Task Group 4440M—Water Use, presented on Apr. 24, 1958, at the Annual Conference, Dallas, Tex., by H. E. Hudson Jr. (Chairman), Hazen & Sawyer, Detroit, Mich. Other members of the committee were Holly A. Cornell, R. J. Devinney, William S. Harris, Harris F. Seidel, and J. B. Wolff.

THE work of AWWA Committee 4440 M—Water Use has been along three lines this past year: [1] assembly of detailed information from specific communities on peak demands, especially for summer loads; [2] collection of long-term data on peak demands and residential sales from a group of privately owned water utilities; and [3] collection and analysis of data from cities covered by a survey of operating data on residential water sales. Limited information on detailed statistics from certain communities has become available. Much more work will be required in this field. The committee has prepared a questionnaire for distribution among utilities. Activities 2 and 3 have been brought to a close this year and are reported in detail below. A partial report on the first item is also included.

Data on sales per account and data from census sources on the number of persons per dwelling were used in calculating the residential sales of water on a per capita basis. Data on the population served were not used because of disparities between the actual number of persons served and census data. In some cases the discrepancies are positive and in some cases negative, depending on whether the system serves all of the census population or not, and depending on whether or not the service area exceeds that covered by the census. Discrepancies as great as 100 per cent were found to be caused by loose application of population data.

Effect of Climate

Figure 1 shows the climatic provinces in North America, according to the Koeppen classification which is used by geographers (*1*). More detailed climatic-province breakdowns are available, but the refinement that they present seems unnecessary for the present study.

Koeppen uses an alphabetical code to designate climatic zones, the key to which is given below.

Aw—moist, tropical; distinct dry season

Bw—Arid, desert

Bs—Arid, steppe

Cf—Warm, temperate; rainy (at least 1.2 in. precipitation in driest month)

Cs—Warm, temperate; rainy (less than 1.2 in. precipitation in driest month)

Df—Cold, temperate; rainy (at least 1.2 in. precipitation in driest month)

Ds—Cold, temperate; rainy (less than 1.2 in. precipitation in driest month).

Subdivision is carried further by additional letter designations, as follows: a—hot summer; b—cool summer; c—cool, short summer; w—rainfall maximum in autumn.

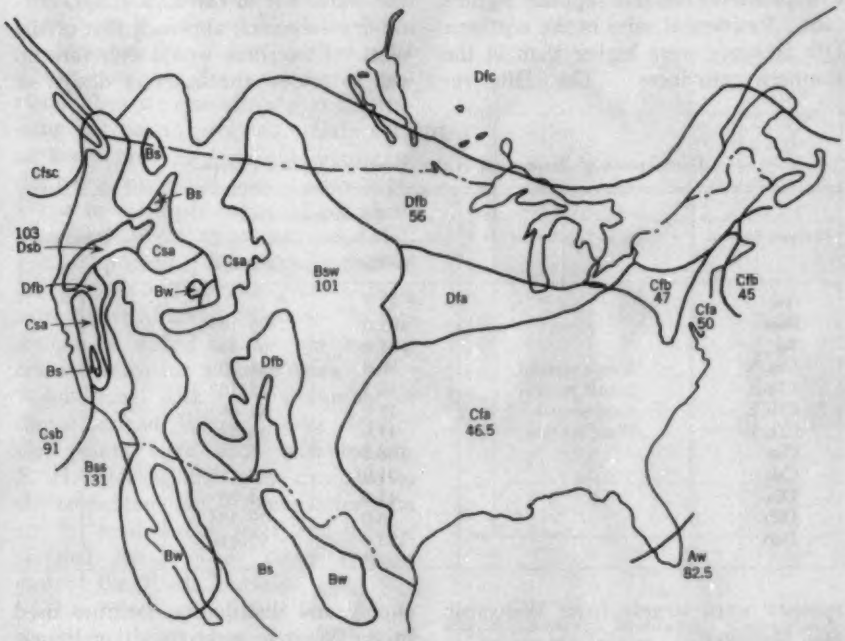

Fig. 1. Climatic Provinces of North America

The numbers given on the map represent median values for metered sales (in gallons per capita per day) in provinces for which these data were available.

These designations appear to cover the climatic characteristics that could be expected to affect water use, especially with relation to lawn sprinkling and air conditioning. Koeppen's classification is rigorously defined by numerical parameters of precipitation, temperature, seasonal variances, and other factors.

The Association has published operating statistics from a large number of water systems in the United States (*2*). Supplemental information on residential sales was collected by the Association through the work of Harris Seidel. Combining these data with information already published in the JOURNAL, information on metered residential sales has been compiled for 113 water systems. These data are summarized in Table 1. It should be noted that the number of systems re-

porting is very small for several of the climatic groups, so that not all the results may be regarded as significant. Median values are shown in Fig. 1, in the areas to which they apply. Geographic coverage was uneven and further reports will be required.

In the eastern United States, differences in sales in the Dfa, Cfa, and Cfb provinces do not appear significant. Residential sales in the northern Dfb province were higher than in the southern provinces. The Dfb responses were largely from Wisconsin and Michigan.

West of the 100th Meridian, residential water sales were uniformly approximately double those east of it. In the more humid, eastern zone, sales ran close to 50 gpcd, whereas west of this zone, they averaged in excess of 100 gpcd. This is a larger difference than reported in previous studies (*3*, *4*), and should be checked further, as returns from western communities were scanty.

Although data are not available to determine precisely what causes the difference in use in the East from that in the West, it may be speculated that the higher residential use in the western United States is due to the liberal use of water for maintaining vegetation. Porges found a correlation of rainfall with total per capita production (*4*).

On the other hand, it is possible that water use in the East could, during dry summers, approach that of the West. Easterners would therefore do well to review the bases of design of supply and distribution facilities used in the West to meet these conditions.

TABLE 1

Distribution of Residential Water Sales by Climatic Provinces

Province Symbol	Special Subdivision	Consumption—*gpcd*		No. of Samples
		Median	Extremes	
Aw		82.5	—	1
Bsw		101.0	96–109	2
Bs		131.0	67–162	4
Cfa-N	North section	50.0	34–70	4
Cfa-S	South section	46.5	25–102	40
Cfb-E	East section	45.0	34–68	5
Cfb-W	West section	47.0	30–78	11
Csa		108.5	—	1
Csb		91.0	76–110	5
Dfa		45.0	24–85	13
Dfb		56.0	29–135	25
Dsb		103.0	97–110	2

Effect of Family Income

Scatter diagrams were made of the relationship between family income and residential sales. Family income data (*5*) indicated a general trend for residential water sales to rise with income, as shown in previous studies (*6*, *7*), but the great scatter of the values indicates that there are other operating variables.

While it might be considered that residential sales in eastern United

States may increase to an order of magnitude approaching those of the West, it seems unlikely, in view of the distinct differences in climate, that this would take place. It seems more probable that there will be a continuing differential in use.

Residential-Requirement Trends

Figure 2 shows the trend in residential water sales at Wichita, Kan., as reported by Robert Millar (*8*). These data are for nonsummer periods when air conditioning and sprinkling are not in progress. Data such as these give an excellent picture of the basic residential sales. They show a rise in sales per service from about 90 gpd in 1922 to an estimated 170 gpd at present. The assumption of 3.5 persons per service gives a basic sales figure of about 48 gpcd. To this should be added an amount for increased sales for summer uses.

Additional data from a number of the American Water Works Service Co. plants have been tabulated by E. H. Aldrich, and made available to the committee (*9*). These latter data are for total annual sales, and include summer uses. They cover systems east of the 100th Meridian.

The trend in residential sales is shown by the average of the sales for these communities (Fig. 3), which rose from an estimated 111 gpd per service in 1939 to 142 gpd per service in 1956, an increase of 28 per cent in 17 years. During the same period, sales at Wichita increased 32 per cent.

Although there have been varied indications questioning the increase in sales per service, it appears that there has been a definite increase of about 2 per cent per year. According to the Wichita data, this increase has been in the basic uses within the homes, exclusive of air-conditioning and sprinkling increases. For the immediate future, an increase in estimated requirements probably can safely be estimated at about 2 per cent per year.

Peak-Demand Data

Additional data have been made available on 51 water utilities operated by the American Water Works Service Co. to show the relation between peak-day flows and average-day flows. These data are shown in Fig. 4, and are averaged year by year. For the systems studied, there is no indication of increase in the ratio of maximum day to average day. The data reported in Fig. 4 indicate that the in-

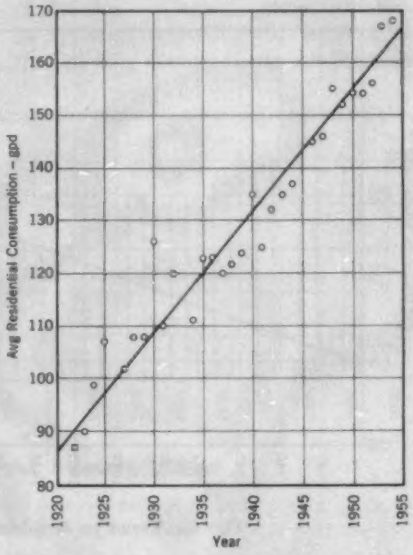

Fig. 2. Average Residential Consumption in Wichita, Kan., 1924–55

These data are for nonsummer months, single-family dwellings only, with no air-conditioning or sprinkling load.

creasing maximum days may be attributed to the general increase in average use. Further data on this point will be necessary, and collection of these data is on the agenda of the committee.

Data available for analysis of peak loads caused by summer uses for lawn sprinkling, air conditioning, and refrigeration were available in some detail from Louisville, Ky. (*10*), Kansas City, Mo. (*11*), and Chicago, Ill. (*12*), divided among the above uses. In addition, data that dealt with the combined sprinkling–air-conditioning load were available for Columbia, S.C. (*13*), and for several water districts in Indianapolis, Ind. (*14*).

Several types of analysis were applied to the data. The first of these involved determination of the relation of maximum-day sprinkling and air-conditioning load, to the typical weekday pumpage. The values are given in Table 2. They may be used for estimating the maximum day, once the typical weekday use is established. The published data from which these values were derived were not assembled to yield this result and the values obtained will probably require modification upon further, more detailed study. The data indicate maximum days having demands ranging from 139 to 177 per cent of the typical weekday.

For further analysis, the maximum-day pumpage was determined, and the maximum draft rates for sprinkling and air conditioning were determined as percentages of the maximum day (Table 2). In addition to these, the sprinkling and air-conditioning loads were separately studied with respect

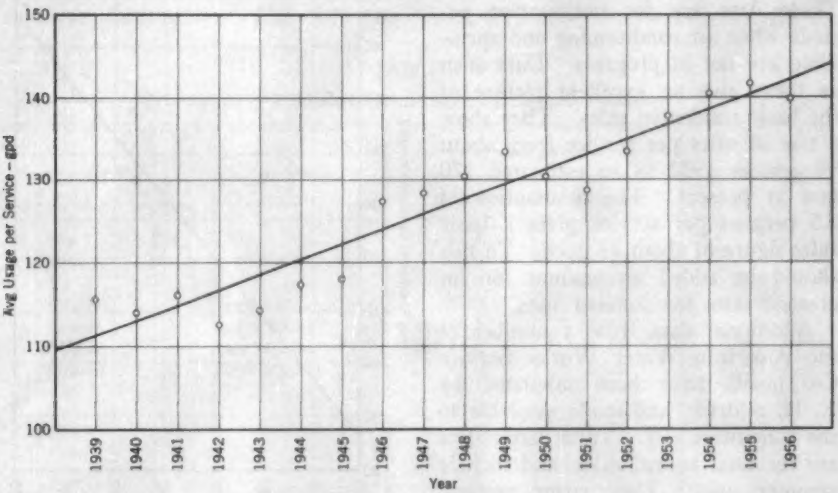

Fig. 3. Trend in Residential Water Sales, 1930–56

This curve, representing the residential-sales trend over a 26-year period, is based on data gathered from 58 systems operated by the American Water Works Service Co., Inc.

to the extent to which they caused pumpage to exceed the maximum-day rate. By means of hourly analyses for each system, it was possible to determine the amount of storage required to meet the demand exceeding the maximum day.

The method of Schmid (*15*) lends itself to revised calculations of storage requirements in the event that pumping is carried on during the maximum day at rates that exceed the maximum-day rate. In this event the storage requirements can be reduced.

character of the community (*15*). On the basis of residential sales of about 50 gpcd, the maximum peak ratio is about 4.5.

Data for the same three communities on the air-conditioning and refrigeration loads show that a high load occurs in midafternoon in the hottest part of the day. There is good consistency in the trends shown for the three cities in Fig. 6, for the hot part of the day. There is some deviation in apparent practice with respect to the morning startup of air-conditioning

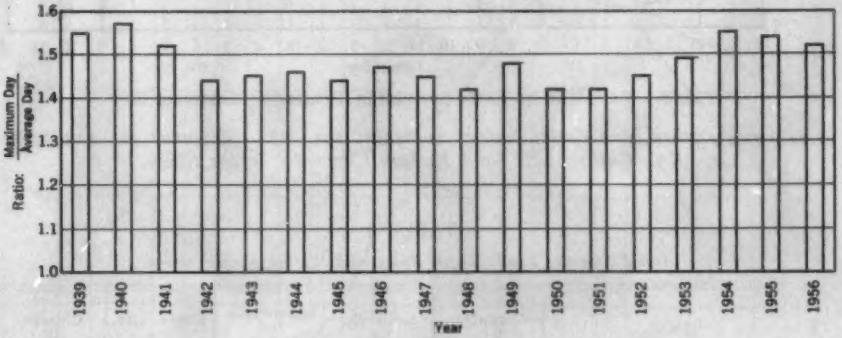

Fig. 4. Variation in Peak Demands, 1930–56

This curve, representing the variation in peak demand over a 16-year period, is based on data gathered from 51 systems operated by the American Water Works Service Co., Inc.

Figure 5 shows the variance in unrestricted lawn-sprinkling load for three of the communities during the heavier-load portion of the day. In each case, an evening maximum for the day occurs. There are variations in the distribution of the load, from city to city, but the data in Fig. 5 may be helpful in estimating the temporal distribution of lawn-sprinkling loads. Data from other sources indicate that the amplitude of the variation may be considerably affected by the size and

equipment, and the effects of climatic-province location are clearly apparent. Because there is no uniformity in classification of accounts with regard to commercial metered sales, it is hard to relate the data in Fig. 7 to basic commercial sales, which range from 20 to 100 gpcd, depending on the nature of the community and the classification of accounts.

The combined effects of air conditioning and lawn sprinkling are generalized in Fig. 7 for the five communi-

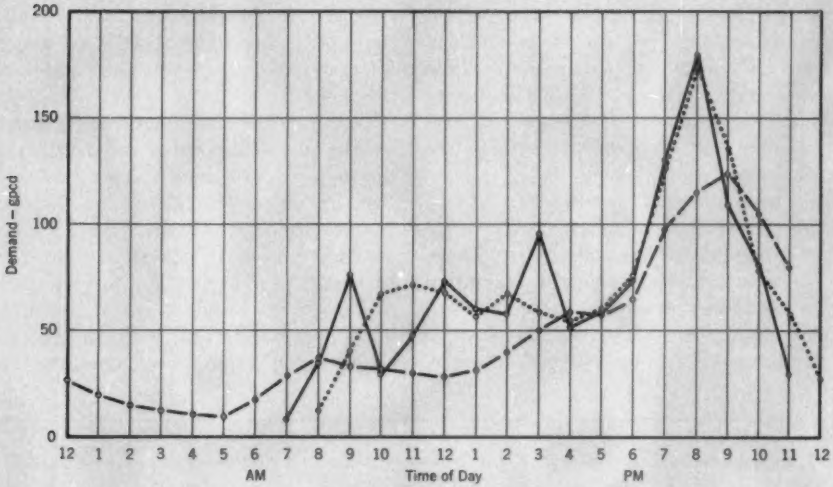

Fig. 5. Variation in Lawn-Sprinkling Demands, Maximum Day

The solid, dashed, and dotted curves represent per capita demands for Louisville, Ky., Chicago, Ill., and Kansas City, Mo., respectively.

TABLE 2

Added Summer Loads, Draft Rates, and Storage Requirements

Item	Columbia, S.C.	Louisville, Ky.	Indianapolis, Ind. N. Dist.	Kansas City, Mo.	Chicago, Ill.
Max. day summer load—*per cent normal weekday pumpage*					
Lawn sprinkling and open hydrants	—	38.4	—	31.8	19.9
Air conditioning and extra refrigeration	—	38.6	—	44.9	19.6
Combined	74.0	77.0	39.0	77.0	39.0
Max. summer hour draft—*per cent max. day*					
Lawn sprinkling	—	70.0	—	64.0	37.0
Air conditioning	—	32.0	—	35.0	22.0
Combined	127.0	91.0	86.0	92.0	48.0
Storage required—*per cent max. day*					
Lawn sprinkling	—	14.7	—	11.5	9.3
Air conditioning	—	12.8	—	10.9	9.6
Combined	24.9	15.1	15.3	12.1	10.5

ties on which data were available. Although there is some deviation in the values, the information should be helpful in indicating the order of magnitude of the values and in estimating temporal variation in loads. With one exception, these curves make sense when considered in the light of the population served and the climatic

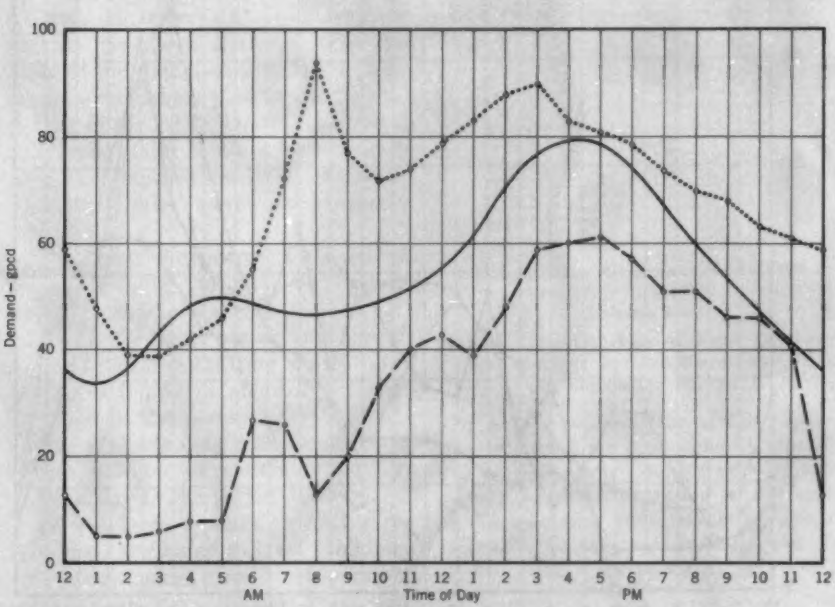

Fig. 6. Variation in Air-Conditioning Demands, Maximum Day

The solid, dashed, and dotted curves represent per capita demands for Louisville, Ky., Chicago, Ill., and Kansas City, Mo., respectively.

province. The apparently low loads at Indianapolis deserve further study.

It should be noted that the heaviest drafts for air conditioning and lawn sprinkling fortunately do not coincide (Fig. 5 and 6). In addition, because the storage values in Table 2 were calculated separately for lawn sprinkling and for air conditioning, the storage quantities calculated for these uses do not add up to the combined-storage ratio required. The calculated combined-storage value is the total storage required to cover all variance above the maximum-day average pumping rate. The values for air conditioning and for lawn sprinkling are respectively the percentages that could have been attibuted to each of these uses independently, assuming that both uses continued as shown.

The maximum draft rates are not the values by which the maximum hour exceeded the maximum-day rate; they are, instead, the draft rates due to either one or both of the summer uses, expressed as a percentage of the

maximum day. They may be used to determine the peak-hour demands by proper synchronization with the appropriate normal-weekday distribution curve. These values are presented to indicate the magnitude of the demand population served, as would be expected. This is illustrated in Fig. 8. It is obvious that the required-storage value for a 1-day peak cannot approach 100 per cent of the maximum day. This has been taken into account in drawing the curve that shows the relationship between population and storage required for these summer uses.

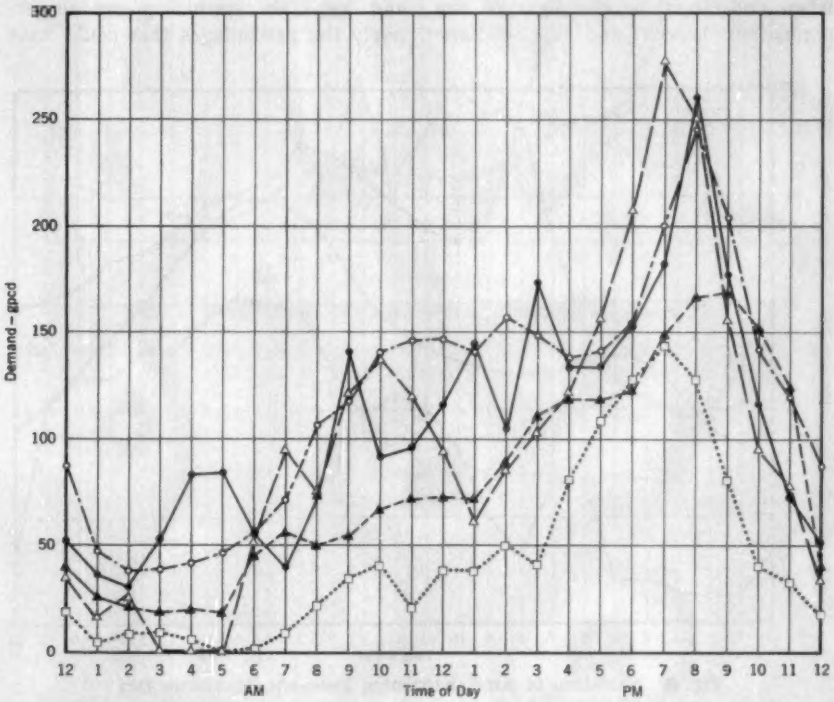

Fig. 7. Variation in Combined Lawn-Sprinkling and Air-Conditioning Demands

The curves represent variation in combined maximum-day demands for the following five cities: ▲, Chicago Ill.; ●, Louisville, Ky.; ○, Kansas City, Mo.; △, Columbia, S.C.; □, Indianapolis, Ind.

problem posed by each of the two summer uses.

Inspection of the data in Table 2 suggests that the peak demand for these maximum summer uses and the storage requirements are related to the

When these data were collected (1954–56), the lawn-sprinkling load

was a more serious demand load than the air-conditioning load. There is evidence that without suitable control measures air conditioning can outstrip lawn sprinkling as a quantity load. Storage requirements for both loads are approximately equal.

Summary

Data on water use from various sources have been analyzed. On the basis of the data available, the following generalizations may be made:

East of the 100th Meridian, metered residential sales were approximately 50 gpcd. West of the 100th Meridian, residential sales were approximately 100 gpcd.

There was a tendency for metered residential sales to rise with rising family income.

Residential sales per service appear to have been increasing fairly uniformly at a rate of about 2 per cent per year in the period 1939–56.

The available data show no increase in the relation of maximum day to average day in the period 1939–56.

In five large systems, special summer loads attributed to lawn spinkling, air conditioning, and refrigeration caused peak days to run 39–77 per cent above corresponding days when these loads did not occur. These rates correspond to additional demand rates of 140–277 gpcd.

Storage requirements caused by the special summer loads in these five communities ranged from 9 to 13 per cent of the maximum day for air conditioning and summer refrigeration, and from 9 to 15 per cent for lawn sprinkling and open hydrants. The increase in storage requirements owing to the combined effect of both uses ranged from 10 to 25 per cent, and seemed to be related to community size.

Maximum hourly draft rates, in the five communities, expressed as a percentage of the maximum-day rate were: lawn sprinkling, 37–70 per cent; air conditioning, 22–32 per cent; combined uses, 48–127 per cent.

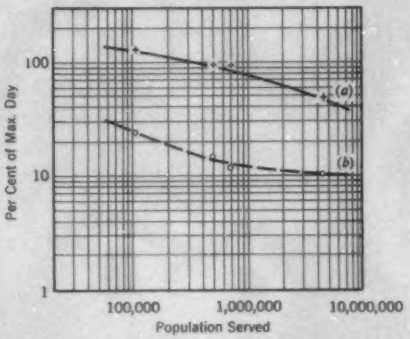

Fig. 8. Relationships of Peak Demand and Summer Storage Requirements to Population Served

The graphs indicate that as the population increases, the peak hour (Curve a) and special summer storage requirements (Curve b), both expressed in per cent of the maximum day (which, of course, increases as the population), tend to decrease.

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Deep Well Standard Revised

On Jan. 26, 1958, the AWWA Board of Directors approved certain revisions to AWWA A100—Standard for Deep Wells, but a new printing was delayed because further changes were under consideration. It has since been decided that these further changes are not warranted, and the standard has therefore been revised to include the changes approved in January. The principal revisions are to Tables 1 and 2 (Sec. A1–5.4); other sections affected are: A1–2.2.1 (Item 7), A1–2.2.2 (Item 6), A1–4.6, A1–6.5, A1–8.3, A1–9.3, and A1–12.2. The designation has been changed to A100–58.

This standard has been adopted by the National Water Well Assn. and is now a joint AWWA-NWWA document.

Carbonate Deposits for Pipe Protection

—Robert F. McCauley and Mahmoud Omer Abdullah—

A paper presented on Apr. 24, 1958, at the Annual Conference, Dallas, Tex., by Robert F. McCauley, Assoc. Prof. of Civ. & San. Eng., and Mahmoud Omer Abdullah, Special Research Asst., both of Michigan State Univ., Lansing, Mich. The study described is being supported by Research Grant G-4627 from the National Institutes of Health, USPHS, Washington, D.C.

DURING the past year, research on protective coatings in water distribution systems has been in progress at the sanitary engineering laboratories of Michigan State University. This work has been directed toward develing procedures that are available in water utility operation for anticorrosion protection for metal water pipes. Studies have been restricted to calcium carbonate–ferric oxide–ferric carbonate deposits, mostly because of the wide use of these "eggshell" coatings in modern water supply practice.

All of the work reported here has been conducted with cast-iron and stainless-steel specimens exposed to demineralized waters containing only calcium hydroxide, carbon dioxide and dissolved gases of the atmosphere, oxygen and nitrogen.

Previous Studies

Evans (*1*) has reviewed the work of a number of authors who have reported on coatings developed in electrochemical corrosion. Quoting Shikorr (*2*), Evans has stated that the oxidation of ferrous hydroxide to hydrated ferric oxide, FeO(OH), results in goethite if the oxidation is rapid and produces the mineral lepidocrocite if slow oxidation takes place. In the formation of lepidocrocite a ferrous-ferrite material is first developed, which in turn yields the hydrated ferric oxide.

Evans (*1*) has also referred to the suggestion that ferrous hydroxide is first formed on the metal face of corroding iron and that exposure to oxygen changes the deposit to the ferric condition. This ferric material in turn reacts with ferrous hydroxide to form green, hydrated magnetite ($Fe_3O_4 \cdot H_2O$), which acts as an intermediate body. The diffusion of oxygen to the green body yields either goethite or lepidocrocite. If there is insufficient oxygen, the green intermediate undergoes dehydration to black inert magnetite. Thus, stratified layers of different iron oxides are often formed in the electrochemical corrosion of iron.

Evans (*1*) has expressed the opinion that rusting iron yields ferrous oxide or hydroxide, which is oxidized to the less soluble ferric oxide. More ferrous oxide then diffuses upwards through the ferric oxide, and iron continues to go into solution in spite of the protective coating of ferric oxide that develops. Calcium carbonate in the presence of oxygen inter-

acts with iron salts to form a clinging, ferric oxide rust. If oxygen is present in large amounts the rust is formed very close to the metal and ferrous salts and calcium carbonate interact to yield ferrous carbonate, which is then oxidized. In the absence of oxygen, loose, unprotective magnetite appears. In agreement with Tillmans, Hirsch, and Schilling (*3*), Evans has also stated that oxygen-free water remains supersaturated with calcium carbonate ($CaCO_3$) but that when oxygen is present the incipient corrosion causes the formation of chalky deposits. According to Evans, calcium carbonate deposits act as a cathodic inhibitor of corrosion.

Stumm (*4*) has experimented with cast-iron specimens exposed to oxygen-saturated water of varying hardness and pH. The coatings developed were removed with sandpaper and found to contain much higher percentages of calcium carbonate in the layers next to the metal surface than in the exterior layers. Outer layers were found to be almost entirely iron oxide.

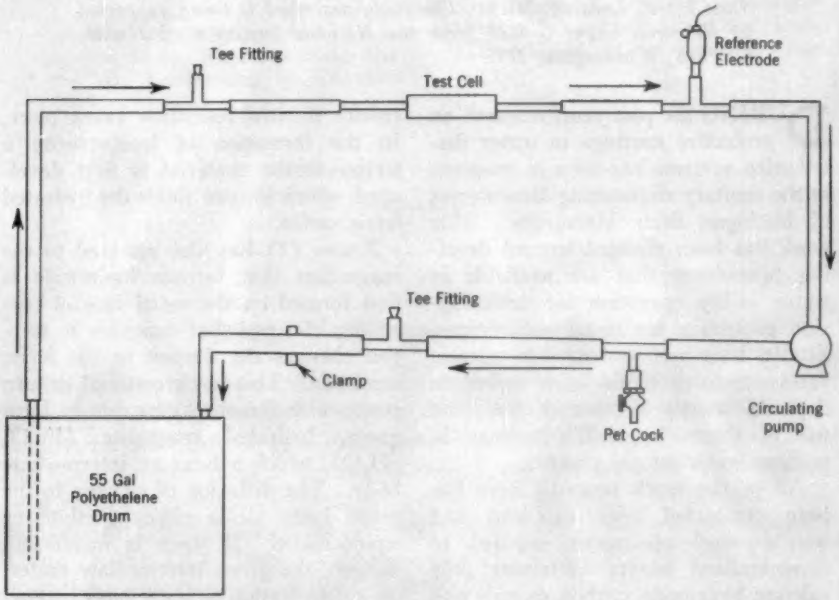

Fig. 1. Flow Diagram of Dynamic Tests With Recirculated Water

The circulating pump was made of rubber. Flow rates were regulated by means of the clamp on the discharge tubing.

Experimenting with the formation of calcium carbonate flakes on glass coils at 120–200°F, Ryznar (*5*) found that incrustation takes place within a 2-hr test period at a stability index ($2pH_s - pH$) of 6 and below. No deposits were obtained at an index value of above 7.5. Because the pH_s

in Ryznar's index was Langelier's pH of saturation, the deposition took place at pH levels of less than 8.0, or when large excesses of calcium carbonate were present in the test waters.

Powell, Bacon, and Lill (*6*) have found that calcium carbonate sometimes fails to deposit in the presence of organic inhibitors such as sewage or decayed vegetable matter. Waters high in sodium alkalinity (as from ion-exchange treatment) produced soft and porous deposits.

Experimental Program

The tests made in this study may be divided into two main categories: static and dynamic.

Static tests were conducted in a glass cylinder 8 in. in diameter and 18 in. high. Each cylinder was filled with 14 liters of de-ionized water of less than 1.0 ppm solids content. Lime and carbon dioxide were added to produce makeup water of the desired pH and hardness.

Two samples of cast iron or stainless steel, 3 in. by 1 in., were totally immersed in each cylinder and attached to a glass rod by means of a resistance wire and rubber band. The immersed portion of the wire was insulated by a waterproof rubber tape. Two glass rods with the samples attached were placed vertically in each cylinder so that the samples were parallel, facing each other, and spaced 4 in. apart. The specimens were cleaned by immersing for 5 min in 0.1*N* HCl, washed with boiled de-ionized water, rinsed with acetone, dried, and weighed before each test. The makeup water was saturated with oxygen and stirred throughout each run by bubbling carbon dioxide–free air continuously, and by keeping the cylinders open to the atmosphere. In some tests a d-c voltage was applied across the samples.

The duration of each run was exactly 1 week. Hardness and pH were periodically adjusted to the desired level. All tests were conducted at room temperature.

Apparatus for dynamic tests included a 55-gal polyethylene barrel, used as a reservoir for the makeup water, which was produced in the same manner as for the static tests by adding lime and carbon dioxide to de-ionized water. The water was circulated through the test cell (Fig. 1) by an all-rubber centrifugal pump at 2 fps. Construction of the lucite test cell is shown in Fig. 2. The test cell acted as a housing for metal samples and permitted measurement of their potentials. The two specimens were mounted parallel in the cell, separated by a distance of $\frac{1}{2}$ in., in order to permit flow parallel to the surfaces.

The cast-iron or stainless-steel samples comprised the only metal in the system. All piping was transparent, flexible tubing with plastic fittings. Oxygen content of the makeup water was kept within 1 ppm of saturation at room temperature. The pH and hardness of the makeup water were adjusted periodically during each study. Specimens were cleaned and weighed before each test in the same manner as for the static tests. Iron determinations showed the level of soluble iron to be low in all test runs.

As in the static tests, during some runs a d-c voltage was applied across the samples, which acted as electrodes. Polarization or open-circuit measurements were made by compar-

ing the potential of each electrode with that of a standard saturated calomel electrode inserted in the line. Polarization characteristics of the electrodes were measured at several intervals during each run by comparing the potential of each electrode with the reference calomel electrode for different current densities. The applied current density was kept constant throughout each run except when polarization measurements were made. Potential measurements were made using a potentiometer and standard-cell technique.

With continuous-flow (dynamic) conditions of 2 fps, better cathode coatings were obtained in all cases than in static tests under similar conditions. Anodes of continuous flow tests also showed relatively better coatings than those for static tests.

In order to check the importance of corrosion in coating development, a dynamic test was made with a stainless-steel specimen that had been sandblasted to increase roughness. The test was made under conditions identical to those which had previously produced a hard, dense coating on cast iron. In this test no measurable coating developed on the stainless steel. In another experiment, however, with a recirculation pump handling supersaturated water, a hard-plastic recirculation line, in which the water flowed at a very high velocity, developed an excellent coating of pure calcite. This showed that electric charge is not essential to the development of a useful calcite coating, provided that the velocity of the water is sufficiently high.

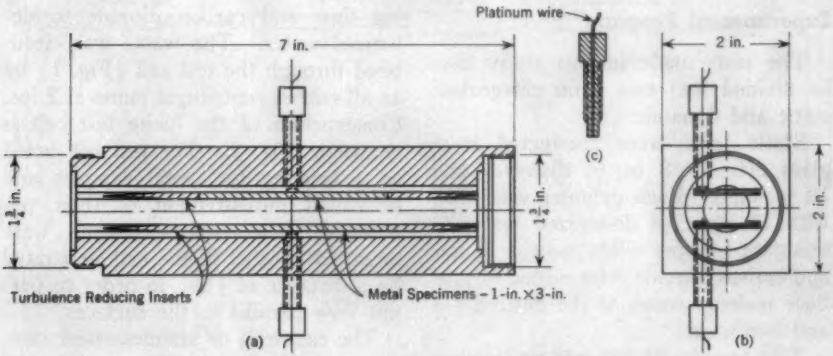

Fig. 2. Construction of Test Cell

The specimens tested in the cell were the only metal in the system. Parts a, b, *and* c *are, respectively: lengthwise cross section; lateral cross section; electrode plug cross section.*

Effect of Electric Charge

It has been noted that, at the level of supersaturation used in these studies, protective coatings developed best when the metal was corroded, or when an outside voltage was applied. Generally, it was observed that better coatings were obtained on the cathodes than the anodes when a voltage was applied across cast-iron or stainless-steel specimens.

Polarization Studies

Figure 3 shows polarization characteristics of the anode and cathode for one continuous-flow test. Cast-iron specimens were employed, and the applied current density was 1.652 milliamperes per square decimeter (ma/sq dm). The curves in Fig. 3, and others (not shown) for 0.826 and 3.304 ma/sq dm, indicated definite cathodic control and showed that the coatings acted primarily as cathodic inhibitors. Cathodic-polarization curves showed a significant shift in the cathodic direction as the applied current densities were increased, whereas anodic-polarization curves showed no significant change.

Colloidal Calcium Carbonate

A series of test studies were made to determine the effect of colloidal calcium carbonate upon the coatings deposited. Colloidal calcium carbonate was prepared in initial tests by forming a supersaturated solution of $CaCO_3$ with lime and carbon dioxide, then adding excess lime water to raise the pH to a value higher than 10. At this high pH colloids were formed, but they were prevented from growing to crystalline size by the quick addition of CO_2 to lower the pH. In later tests lime and carbon dioxide were added to the demineralized water until colloids were observed at the desired pH level. This procedure determined the hardness required to produce a good coating at a particular pH value. All recent tests have utilized this latter method.

Dense protective coatings were formed in studies where the makeup water contained this colloidal $CaCO_3$. Coatings on samples from tests made under identical conditions without colloidal material were softer and formed a poorer bond with the metal. Especially good coatings were obtained when colloidal calcium carbonate was present and when flow velocities were about 2 fps. Under these conditions, a relatively hard and tenacious coating formed within a period of 1–5 days.

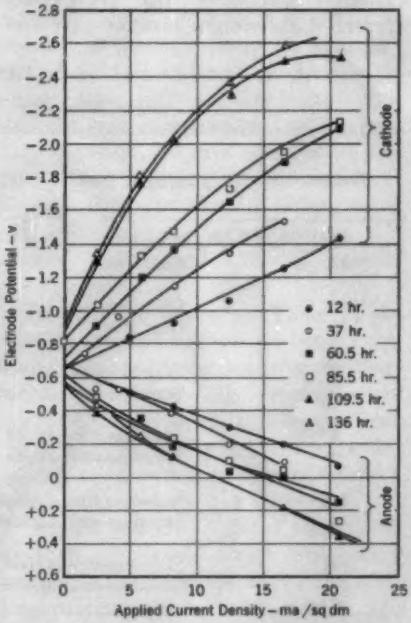

Fig. 3. Cathode and Anode Polarization Characteristics for a Continuous-Flow Test

The shift in polarity of the cast-iron cathode after deposition of calcium carbonate indicates that the latter acts as a definite cathodic inhibitor.

Calcium carbonate crystals of greater than colloidal size did not have as favorable an effect on coating formation as did the colloidal form. The crystals showed a typical calcite structure under the microscope and carried no electric charge.

Changes in Weight

Table 1 shows the effects of colloidal $CaCO_3$ in static tests. The "weight gain" in this table is the weight of the $CaCO_3$ coating deposited on stainless-steel specimens. The "weight loss" is the metal lost after cleaning the corrosion products from cast-iron specimens with an electric eraser. Less weight loss for cast-iron specimens and more coating of stainless-steel specimens resulted in tests where the makeup water contained colloidal $CaCO_3$ than when colloids were absent, all other factors being the same.

TABLE 1

Some Static Tests With Colloidal $CaCO_3$

Test No.	Sample	Weight increase to formation of coating g	Weight loss after removal of corrosion products g
11*	Cast iron		0.1952†
12	Cast iron		0.2264†
16*	Cast iron		0.2685‡
15	Cast iron		0.3637‡
8*	Stainless-steel cathode	0.0550	
9	Stainless-steel cathode	0.0048	
8*	Stainless-steel anode	0.0059	
9	Stainless-steel anode	0.0004	
14§	Stainless-steel cathode	0.0007	
13	Stainless-steel cathode	0.0005	
14§	Stainless-steel anode	0.0012	
13	Stainless-steel anode	0.0003	

* Colloidal $CaCO_3$ present.
† Positive Langelier index.
‡ Negative Langelier index.
§ Crystalline $CaCO_3$ present.

Determination of Electric Charge

Electrophoresis methods were used to determine the electric charge of colloidal $CaCO_3$. Migration of the colloids in a U-tube with platinum electrodes caused increased turbidity at the cathode at pH 6–11. Since this finding was not in agreement with that of Larson and Buswell (*7*), further tests with excess sodium carbonate and calcium chloride were made. Also, powdered calcium carbonate was ground in a ball mill for 20 hr to produce colloids. All tests continued to show migration to the cathode, which indicated a positive charge on the calcium carbonate colloids.

Mineral Content

Examination of minerals deposited upon the cast-iron specimens showed that the coatings consisted of mixtures of calcite (calcium carbonate), limonite (hydrous ferric oxide, chiefly goethite) and siderite (ferrous carbonate).

Mineral examination was performed by the Michigan State University Ge-

ology Department by petrographic methods. Index oils of 1.58 and 1.80 were used. The mineral below 1.58 was calcite, the material above 1.80 was limonite and the intermediate mineral was siderite. The percentage of each mineral was estimated by the methods described above. Identification and percentage values were checked by use of dilute hydrochloric acid for effervescence comparison. The minerals were also studied under crossed polarizing prisms and the properties observed corresponded to those described for these minerals in textbooks on petrographic mineralogy.

Microscopic examination revealed ridges and valleys on all cast-iron samples. The ridge formation was particularly noticeable for samples from dynamic tests. Most of the calcite observed was found in the valleys, whereas ridges were commonly limonite at the surface with siderite deposited below near the metal.

Calcite showed typical rhombs on the stainless-steel specimens. In the valleys of cast-iron specimens some calcium carbonate crystals were noted, but the calcite was commonly amorphous. Ridges were predominantly hydrous ferric oxide in the form of limonite, and some calcite often was present. Siderite was commonly found in very fine crystals. Limonite was not crystalline, and was observed in the amorphous form only.

In most studies with cast-iron specimens, the coatings were largely limonite; with stainless steel, only calcite was found.

Effect of Momentary Excess

Dye (*8*) has defined "momentary excess" as that fraction of the calcium and carbonate ions present in an aqueous solution which is in excess of the solubility product constant of calcium carbonate. Momentary excess is invariably less than Langelier's solubility excess, which is the amount of calcium carbonate precipitation that must take place to bring a calcium carbonate–bicarbonate–carbon dioxide system into equilibrium.

Table 2 shows momentary and saturation excesses for waters which were studied in dynamic tests. It is apparent that high momentary excess resulted from high pH levels, and that low pH values produced low momentary excess. Because momentary excess should represent the driving force in calcium carbonate deposition, some relationship should exist between this excess and the rate of calcite precipitation.

In all tests shown in Table 2, the water contained calcium carbonate colloids because of the superior coatings which were found to develop when these colloids were present. Tests were run for the length of time required to produce a definite coating, which was usually 1–5 days.

Tests 1 and 2 of Table 2 were made at high pH levels (high momentary excess). On these specimens the coatings were high in loose-grained and chalky calcite, with very slight bond with the metal. The coating could be removed by scraping with one's fingernail.

Momentary excesses for other tests in Table 2 were of a much lower order than for the first two high pH studies. Hard, dense coatings were developed on all specimens, with good to excellent bond with the metal. From a hardness and bond criterion, it was considered that the anticorrosion value of these coatings was in inverse ratio to the momentary excess. That is,

low momentary excesses gave superior coatings.

In dynamic tests calcium carbonate was removed from the water at a rate of 10–55 ppm, or about 1–5 g per day. Only a small part of this material was deposited on the test specimens; however, the remainder was deposited in the flexible tubing of the apparatus.

In one test at pH 8.3 and momentary excess of 4.0, two identical 1-day runs were made with the same test water, the second test being made 4 days after the first. The only difference between the runs lay in the age of the colloidal material in suspension. The precipitation rate in the first test was 15 ppm per day, and in the second test it was 50 ppm per day. Both runs produced good protective coatings in a day's time. The coating of the first test specimen was of a smoother texture, however, and did not show very marked ridges and valleys as did the second specimen.

From this and other experiences it appears that older and probably larger calcium carbonate colloids increased the rate of deposition while they maintained a tenacious bond and produced a relatively hard coating material.

Discussion

In all tests with cast iron, the specimens were subjected to extremely rigorous conditions. Specimens were machined and thoroughly cleaned so that no protective film or coating was initially present. Test water in all cases was nearly saturated with dissolved oxygen. In this environment, rusting was rapid.

For initial static tests corrosion was rapid and soft, poorly bonded coatings developed. In general, these coatings were mixtures of calcium, ferrous carbonate, and iron oxide, bonded to a porous layer of rust. The coatings could be removed from the specimens with a fingernail. In static tests with colloidal calcium carbonate more satisfactory coatings were obtained, but none appeared to be of the type desired.

Initial dynamic tests were disappointing since coatings were also soft and poorly bonded to the layers of rust that developed on the metal surface. Later studies, with identical conditions

TABLE 2

Relationship Between Saturation Excess, Momentary Excess, and Type of Coating Developed

pH	$CaCO_3$ *ppm*	Saturation Excess*	Momentary Excess†	Relative Protective Value of Coating Developed
10.25‡	83	66.5	46.5	7 (poorest)
10.25‡	65	48.5	34.7	6
8.6‡	150	30.0	5.4	4
8.7‡	120	22.0	5.1	5
8.4‡	205	44.0	5.0	2
8.3‡	200	44.0	4.0	1 (best)
8.6§	92	14.5	2.7	3

* Experimentally determined.
† Calculated by Dye's method (*8*).
‡ Colloid developed at pH level indicated.
§ Colloid developed by raising pH above 10.0, then adjusting with CO_2.

to the first dynamic tests, but made in the presence of colloidal calcium carbonate, produced hard coatings with good to excellent bond with the metal.

In the presence of calcium carbonate colloids, the test waters were observed to move rapidly toward equilibrium and this resulted in useful coatings. It would seem that the development of good anticorrosion protection requires an initial deposit of dense material that is well bonded to the metal. This layer need be but a few molecules thick. Upon such a foundation a hard and tenacious coating can then be developed.

Even with the rapid development of this initial coating, corrosion did not appear to be completely stifled, as evidenced by the presence of ferrous carbonate (soluble to 60 ppm in water) below the outside layer of iron oxide. Continued corrosion was also evidenced by the large percentage of iron found in the coating deposits.

Calcium carbonate remains in supersaturation for long periods of time unless the reaction rate is increased by the presence of crystal nuclei or by energy in the form of turbulence, high velocity, or heat. The rapid development of the coatings described is therefore attributed to the catalyzing action of the colloidal calcium carbonate and to the relatively high velocity of the water. Whether the positive charge associated with the colloids is an influencing factor has yet to be determined.

The action of the calcium carbonate in developing good protective films also seems to lie in improving the bonding of the hydrous iron oxide (limonite) to the metal. Calcite and limonite were found in physical, but not chemical, mixtures. These mixtures bonded well with the cast-iron specimens, and were hard and relatively tough.

Because high momentary excesses produced heavy layers of loose, chalky calcite, a high rate of calcium carbonate deposition has not seemed desirable. On the other hand, large solubility excesses of 30–50 ppm or more of calcium carbonate (with low momentary excess) appeared to be helpful since the rapid growth of a good coating then resulted.

The practical value of the procedures used in this work is yet to be determined, because no method for properly evaluating the anticorrosion protection afforded by the coatings has been developed. Judgment of coatings on the basis of bond with the cast iron, hardness, and toughness has been reasonably satisfactory for these studies, but a better method of evaluation is desirable.

It is well recognized that these tests do not parallel conditions that normally develop in water distribution systems. It is also recognized that in newly cleaned cast-iron mains such coatings as are described here may or may not be of value in the distribution system over a period of years. The authors do not consider these limitations important at this time, because the emphasis of this work is upon basic studies and not the development of practical procedures.

Conclusions

The following conclusions may be drawn from investigations reported in this paper:

1. Formation of protective calcite–limonite–siderite coatings on cast iron occurred best when the specimens were corroded or when outside current was impressed through the specimens.

With stainless steel, no observable calcite coating was developed except when a current was impressed.

2. Coatings developed in the study acted primarily as cathodic inhibitors.

3. High flow rates were desirable for the formation of hard, durable coatings. Static tests produced soft coatings that could be easily removed.

4. Better protection and better-bonded, harder, and tougher coatings resulted with solutions containing colloidal $CaCO_3$ than from solutions of the same pH and hardness with no colloids present.

5. Calcium carbonate crystals in suspension did not have a favorable effect on formation of coatings from supersaturated solutions.

6. Colloidal $CaCO_3$ had a positive charge in the pH range 6–11.

7. A high momentary excess of calcium carbonate led to the formation of chalky calcite coatings, which were soft and could be removed with a fingernail. Low momentary excesses and high total excess of calcium carbonate led to the formation of tenacious, hard, protective coatings within a day.

8. The coating materials developed were largely hydrous ferric oxide in the form of limonite. Their composition was usually 5–40 per cent calcite. Siderite was usually observed close to the metal surface in ridges of cast-iron samples.

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Current Research on Corrosion and Tuberculation of Cast Iron

Thurston E. Larson and R. V. Skold

A paper presented on Apr. 24, 1958, at the Annual Conference, Dallas, Tex., by Thurston E. Larson, Head Chemistry Section, and R. V. Skold, Research Assoc., both of the Illinois State Water Survey, Urbana, Ill. This report was prepared for AWWA Committee 2810 D—Effect of Purification Methods on Water Main Carrying Capacities, whose function is to advise, assist, and supplement the study being conducted on this subject by the Illinois State Water Survey. The study described is being supported by Research Grant G-4007 (R) from the National Institutes of Health, USPHS, Washington, D.C.

THE objective of this research is to study the effects of mineral content on the corrosion and tuberculation of cast iron pipe with specific reference to loss in carrying capacity through tuberculation. Space does not permit a review of the previous research (*1–3*) reported on this project. This report will present only a brief summary of the more significant findings in the past year.

Fresh Cast-Iron Surface

The freshly cast, unground, interior surface of cast-iron pipe has been found to have a high resistance to corrosion by water (*1*). In order to determine the composition of this surface, a specimen was submitted to W. H. Bruckner of the University of Illinois Department of Metallurgy. Figure 1 shows a microphotograph (50×) of an unetched mount. Two layers are present on the surface.

When the surface was scraped off of the interior of the cast iron, the black phase (between the metal surface and the gray phase) was found to be ferromagnetic magnetite (Fe_3O_4) with a cubical structure. The gray phase on the internal, exposed surface (adjacent primarily to the magnetite) showed two or more components under polarized light: [1] long, needle-like pyroxenes of monoclinic structure, such as $CaSiO_3$, or $FeSiO_3$; and [2] polyhedron garnets of cubical structure, such as $Ca_3Al_2(SiO_4)_2$ or $Fe_3Al_2(SiO_4)_2$. This silicate "skin" is apparently responsible for the excellent resistance to corrosion by water. It is, however, quite brittle and therefore only of academic interest.

Present Studies

One laboratory study, still in progress, is being conducted to show the effect of pH on the corrosion rates of cast iron at a flow rate of 0.1 fps for a particular zero hardness water having an alkalinity of 125 ppm and a chlorine-alkalinity (Cl/alk) ratio of 0.2. Corrosion rates are given in milligrams per square decimeter per day (mdd). The results shown in Fig. 2 are similar to those obtained for steel specimens (*1*) in that the lowest average corrosion rate occurs at pH 7.0. Severe local pitting was noted at the edge of the paraffin coating over the edges.

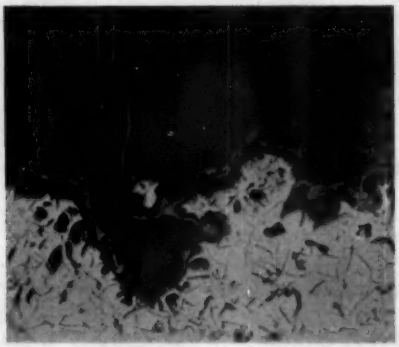

Fig. 1. Microphotograph of an Unetched Mount of Cast Iron

The outer, dark edge of the sample is composed of silicates and aluminosilicates; the intermediate, gray stage is composed of magnetite; and the inner, light-gray stage is the actual ferrite. This microphotograph was taken at 50×.

Tuberculation on the machined cast-iron surface increased with increasing pH in the range 7.5–9. The corrosion products at pH 7 appear to be effectively resistant to the diffusion of dissolved oxygen.

Another test, designed to determine the relative influence of sulfate and chloride ions on tuberculation, showed no significant difference with regard to corrosion rate or tuberculation in concentrations up to 30 ppm sulfate and 3–25 ppm chloride with water of an 85-ppm calcium hardness, a 120-ppm alkalinity, and 0.29 $(Cl + SO_4)$/alk ratio at saturation indexes of −0.8, −0.3, and 0.0.

Another study has been made to discover the effect of the Cl/alk ratio on the corrosion of machined cast iron in waters with an alkalinity of 125 ppm at calcium concentrations of 30 ppm and 85 ppm. The pH was regulated

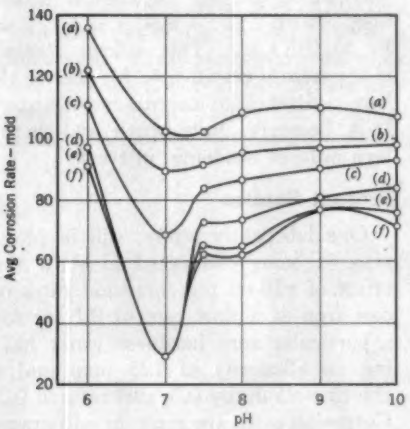

Fig. 2. Relationship of Corrosion Rate to pH

Curves a, b, c, d, e, *and* f *represent corrosion rates at periods of 1, 10, 20, 50, 100, and 150 days, respectively, at the indicated pH.*

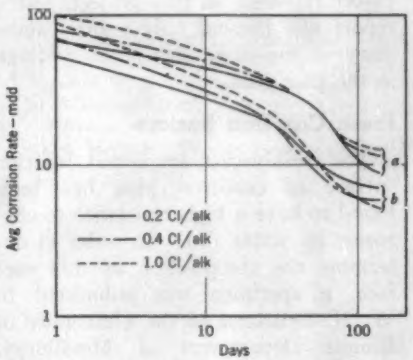

Fig. 3. Decrease in Average Corrosion Rate With Time

The curves of Group a *represent runs with 0.6 epm Ca at pH 8.2; those of Group* b *represent runs with 1.7 epm Ca at pH 7.8. For all runs the saturation index was 0.0, linear velocity was 0.8 fps, and alkalinity was 2.4 epm.*

to maintain a zero saturation index. The corrosion rates for this study are shown in Fig. 3. It can be seen that the relationship of increased corrosion rate to increased Cl/alk ratio is minimized within 30 days when the water is stabilized with $CaCO_3$. The beneficial effect of higher calcium hardness is shown even though the pH is lower.

New Test Chambers

A newly designed corrosion test chamber, which is being evaluated for use both as a laboratory and field device, is shown in Fig. 4. This particular chamber has six cast-iron specimens, two in each of the three sections defined by the water flow outlets. The test chamber itself is made of clear lucite and the water flow channel is 0.4 × 1.4 in. in cross section. The calomel and platinum electrodes serve to measure relative corrosion rates (*4*). The three outlets provide means for testing the effects of water flow velocity. This corrosion test chamber

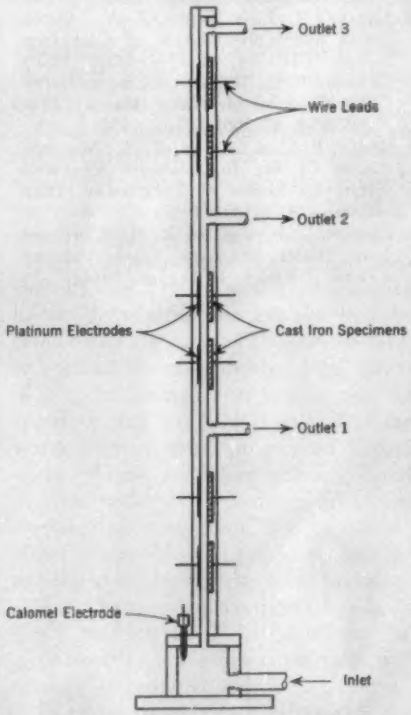

Fig. 4. Corrosion Test Chamber

The calomel and platinum electrodes permit measurements of relative corrosion rates; the outlets provide a means for testing the effect of flow velocity.

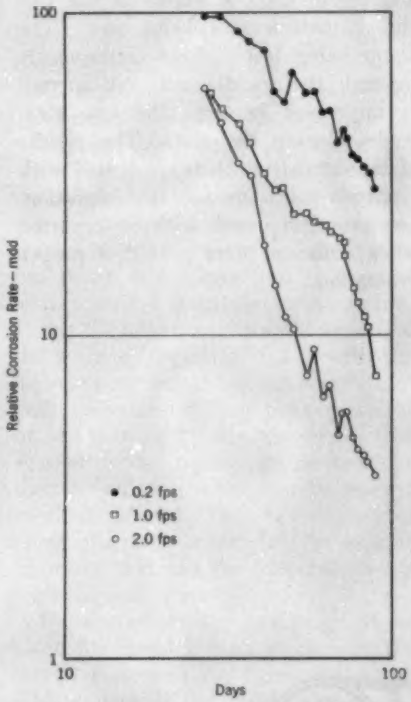

Fig. 5. Effect of Water Flow Velocity on Corrosion Rate

The three curves represent relative corrosion rates with Champaign–Urbana tap water over a period of 85 days at the indicated flow velocities.

may have many applications, particularly at water plants, where a continuous test of the corrosive nature of the water used is desirable. Figure 5 shows the results with Champaign-Urbana tap water for a period of 85 days during which this test chamber was used.

Another project under way is a study of the behavior of particular ions in water at the anode and cathode of a corrosion cell. For this study, a nine-compartment cell (*5*), which has anode and cathode plates in the two end compartments, is being used. The water being tested flows continuously through the middle cell. A current is impressed between the two electrodes during the test. The results of this study, which is concerned with electrode reactions and ion migration, are promising and will be reported when sufficient data permit a proper evaluation.

Acknowledgment

The physical facilities for the laboratory investigations were furnished by the Illinois State Water Survey. The authors wish to thank Mary C. Brooks, of the Illinois State Water Survey, and Donna Winn, of the University of Illinois, for their laboratory assistance.

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Finding Sites for Elevated Tanks

Clyde E. Williams

A paper presented on Apr. 22, 1958, at the Annual Conference, Dallas, Tex., by Clyde E. Williams, Pres., Clyde E. Williams & Assoc., Inc., South Bend, Ind.

THE selection of a site for a proposed elevated water storage tank is important. This phase of planning usually comes after the determination of the volume and type of storage (whether ground or elevated), although it may in some cases have to be taken into consideration initially.

Once it has been established that an elevated tank is to be built, and the amount of storage has been determined, the selection of the general location, and, finally, the actual site or sites, is dependent upon these three basic considerations: [1] how the deficiencies in the distribution system can best be reduced by the tank; [2] how the tank will affect the neighborhood in which it is to be located and how it will be received; and [3] how it will affect the water improvement project on a cost basis. These considerations are listed in their order of importance from the engineering standpoint, but, of course, either the problem of public acceptance or limited funds could be more pressing.

After proper consideration has been given to each of these questions, the possible sites for the elevated tank will usually be reduced to two or three.

In order to elaborate further on the problems in locating the elevated tank, the basic considerations will be placed into three categories: [1] engineering; [2] public relations; and [3] economics.

Engineering Considerations

The prime engineering concern should be the improvement of service, pressures, and fire protection for the community as a whole. If possible, improvements should be in the area most deficient in these necessary requirements of a water system.

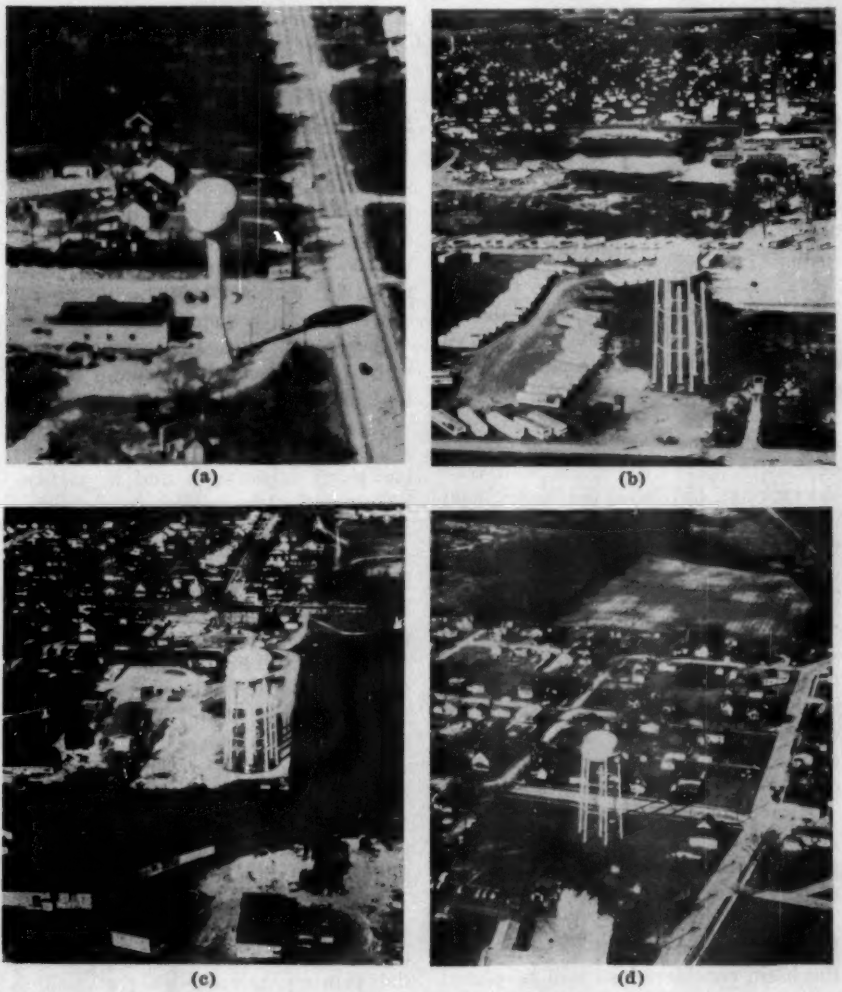
A great many design engineers and water utility men believe that a storage tank should be located so that the high volume use lies between the pumping station and the storage. This system has many advantages and is particularly practical in smaller communities. It has the advantage that the center of the system (usually the area with the highest peak demands) can be fed from both directions during peak demands or fire demands. It often means that smaller feeder mains can be used or that the existing mains can be utilized to their fullest. This has the added effect of greatly increasing the volume of water that can be delivered to the high-demand area.

It is occasionally advantageous to place the elevated tank at or near the pumping station or treatment plant. This is true if the deficiencies in the system would not be improved by placing the tank out on the system and if the primary purpose of the tank is additional storage.

The location of the tank near the pumping station usually reduces the

pumping head and, consequently, the power costs. In existing systems it sometimes permits the use of pumps, motors, and piping that might otherwise have to be replaced by higher-head and higher-capacity equipment.

Under certain conditions it may be advantageous to erect the tank near the filtration plant so that elevated storage can provide the backwash volume and pressure needed to eliminate the necessity for a backwash pump. In some



(a) (b) (c) (d)

Fig. 1. Examples of Modern, Attractive Elevated Tanks

The tanks pictured above are from the following cities: Fig. 1a, Griffith, Ind.; Fig. 1b, Bremen, Ind.; Fig. 1c, Plymouth, Ind.; Fig. 1d, Rochester, Ind. Details in text.

smaller communities, aeration of the water in the elevated tank may also be considered as a part of water treatment.

Some engineers choose the highest elevation in the distribution system for the location of the elevated tank. In some systems where terrain and the existing water mains permit the location at the highest point, it is, of course, expedient to do so. It may be more prudent to add to the height of the tank (at, say, $500 for every foot) than to install large feeder or arterial mains over long distances at approximately $10 per foot. It should be pointed out that one of the functions of an elevated tank is to maintain adequate, uniform pressure. When a tank is placed on much higher ground than the rest of the system, care must be taken that none of the lower elevation areas have excessive pressures.

Once the general location of the elevated tank has been determined, selection of the specific site must be based upon several additional engineering requirements. It must be of adequate size to facilitate the construction and the storage of materials during erection of the tower. The site must be on well drained land, and located on soil that has suitable bearing values to support the structure. It has become the practice to make soil borings and have bearing tests made before the actual site is recommended for construction. Provision should also be made for handling overflow and waste drainage.

The tank must be placed on a site where it will not be a hazard to aircraft along civil airways. Civil Aeronautics Administration regulations specify that any structure 150 feet high or higher along, or within 20 miles of, a civil airway, must be approved for construction by CAA. Most elevated tanks do not reach 150 feet above ground level, but it is a good practice to check with CAA before finally deciding on a particular site.

Public Relations

The next considerations in the choice of the tank site are its effect on the surrounding area and the winning of neighborhood acceptance. After having given careful study to the problem of choosing a location from an engineering standpoint, one dare not neglect the public relations aspects. A slogan adopted by the Engineers Joint Council regarding public relations is "good performance, publicly appreciated, because adequately communicated." The perfect engineering design would be inadequate if not publicly appreciated because it had not been fully explained and discussed.

In the author's experience, by far the larger percentage of elevated tanks for small communities are constructed in residential areas, because it is in these areas that problems of supply, small mains, and area growth are most common. These are the major problems of the local government officials and the water works departments.

Water storage structures do not necessarily devalue property, and once in place they are regarded as indispensable necessities. Residential home areas are developed around them without further worry about their location.

In recent years tank companies have improved the design and appearance of tanks. With the new ellipsoidal and spherical designs and the tubular columns, elevated tanks are no longer objectionable in appearance. The tank, if it is well designed, should have a prominence which is a constant reminder of its valuable service to the community.

An elevated storage tank may also be a landmark for a community. The traveler can be informed miles ahead of the name of the community he is approaching, if the name is painted in large black letters on an attractively painted white or pastel tank. Therefore, when picking the site for a tank, some consideration may be given to its prominence as an advertising medium for the community.

There are many tanks located in residential or semi-residential areas. It should not be necessary to change a site simply because the citizens object to having a tank at the old site. The engineer, of course, should attempt to prepare officials for possible objections by showing pictures of beautifully painted, pleasing tanks in other communities, or by asking them to talk to residents in the areas where such tanks are located. Such an approach should succeed in overcoming any objections.

Some citizens object to the location of an elevated tank in a residential area owing to the possible danger of its falling during a tornado or storm. This objection can be countered by pointing out that after the tornado in suburban Kansas City, Mo., in 1957, the only structure remaining erect and undamaged was the elevated storage tank, which was designed to withstand the onslaught of wind and weather.

Another thing that the engineer and community officials should consider is the possible benefit to local industries. By erecting an elevated tank near industry, storage and pressure can be provided for both domestic and industrial use. There are many examples of industries that have been able to install sprinkler systems, thereby reducing their insurance rates, by a cooperative effort in the placing of a tank.

By using trees and shrubbery, the elevated tank columns and piers can be easily camouflaged at eye level. This may reduce many of the objections of people whose homes are adjacent to the tank.

A 250,000-gal, double ellipsoidal tank at Buchanan, Mich., painted white, was built on high ground in part of the city where the pressure and supply were low. With the tank at this site, the area of high-volume use is between the well pumps and the storage. The site is in a residential neighborhood opposite a new grade school. No objections were raised by citizens in the area except by one person who had a high radio antenna and claimed that the tank would affect his reception.

Highland Ind., has a 500,000-gal tank painted sage green. It is on high ground and has only a 60-ft tower. This tank is also an advertisement for the town, being located on a much-traveled east–west highway. Trees cover the legs of the tank from the nearby homes and the residents seldom realize that it is there.

A 200,000-gal capacity spherical tank, painted light green, and located just a few miles down the highway from the Highland tank, is shown in Fig. 1a. It is in a low-pressure commercial area, and provides good advertising for Griffith.

The tank shown in Fig. 1b is in an industrial area of Bremen, Ind. The industries are to the left along the Pennsylvania Railroad. It is a 300,000-gal tank and is painted light blue. Three of the industries were able to provide sprinkler systems for their plants, thereby reducing their fire insurance rates by a considerable amount. The town is in the upper right of the photograph.

The 400,000-gal tank shown in Fig. 1c is located on city-owned high ground, a logical location because most of the high water-consuming industries are near this site. The tank is at the opposite end of the city from the well field, and the main part of Plymouth lies between these points. There also is a 100,000-gal elevated storage tank located in the central district. The tank is light green color and holds 400,000 gallons.

Figure 1d shows a tank located near a large feeder main in the industrial and future industrial-growth area of Rochester, Ind. The new tank, together with another large feeder main constructed at the same time, completed a very strong grid throughout the city between the wells, treatment plant, and an existing 100,000-gal elevated tank. This tank holds 300,000 gal and is painted blue.

Economic Considerations

The last consideration in the choice of a tank site is how the cost of the overall project will be affected by the selection. Two of the significant factors are: [1] the cost of feeder mains to get the water to and from the tank; and [2] the cost of the site. Many times odd-shaped parcels of land, or areas which do not particularly lend themselves to building construction, can be purchased at a reduced cost. Sometimes industries will donate the land for the consideration of having the tank located near them.

Conclusion

The location and the choice of the elevated storage tank site must be unanimously agreed upon by all concerned—the engineer, the community officials, the board of health, the fire underwriters, the local industries, and the individual citizens. It should always be kept in mind that the location selected should meet community needs, provide dependable service, and have public approval.

Plastic Pipe in Distribution Systems

—A Symposium—

A group of papers presented at various section meetings that briefly discusses the use, performance, and practicability of plastic pipe in water distribution systems.

Uses and Performance—*Richard King*

A paper presented on Mar. 25, 1958, at the Southeastern Section Meeting, Atlanta, Ga., by Richard King, Prof. of Civ. Eng., Georgia Institute of Technology, Atlanta, Ga.

Plastic materials have become increasingly commonplace in our way of life, and there is a growing interest in the use of plastic pipe for underground water lines. This relatively new material in the water supply field has aroused the interest of engineers and water utility operators, and considerable study and research are currently being conducted to determine its applications in water transmission. The problem of rising costs plagues every industry, and most certainly the water industry is no exception. To reduce these costs, a continuous, selective search is being carried on to find more inexpensive and efficient equipment and materials. Because it has a number of desirable characteristics, plastic pipe is being extensively studied, and used on trial bases, to determine its applications to the specific needs of the water industry.

In 1931 polyvinyl chloride compounds (*1*) were developed by German scientists who proceeded to put millions of pounds into use, some of it in pipes. With the advent of World War II, and in the period following the war, the scarcity of materials and the high cost of labor focused greater attention upon the possible use of plastics. It was in 1950 that this material really entered the water field, and the plastics industry has grown until now it is a major industry.

In general, plastic pipe has the following advantages over metal pipe:

1. Its resistance to rust, corrosion, and chemical and electrolytic attack
2. Its ease and economy of installation
3. Its light weight, long lengths, and workability
4. Its possible elimination of some fittings
5. Its excellent hydraulic characteristics
6. Its minimal collection of solids deposits
7. The low capital investment in equipment required to produce it
8. Its low initial cost, in most instances
9. In other instances, the fact that the higher initial costs are cancelled by the elimination of replacement costs

Definition

One technical dictionary defines plastic as "a substance that can be melted." This obviously includes many

materials. Webster's gives the definition: "A plastic substance; specifically, any of a large group of organic, synthetic, or processed materials that are molded or cast and used for making many articles, and are a substitute for glass. Some are cellulose derivatives, some protein, and many are resins formed by chemical condensation or polymerization. Rubber and similar materials are sometimes included among plastics." This definition covers many substances with various physical and chemical properties. Many plastics are now known by their trade names.

A plastic usually contains from one to eight of the following ingredients:

1. A resin or cellulose derivative as the principal ingredient
2. Carbon black, used as a coloring or added to prevent possible deleterious effects of light penetrations
3. A mold lubricant to prevent the plastic from sticking to the mold as the pipe is extruded
4. A plasticizer to soften, increase the toughness, or otherwise modify the properties of the binder
5. An antioxidant to prevent or retard oxidation
6. Accelerators to aid in the vulcanization of rubber
7. Stabilizers to lower surface tension, or to act as emulsifiers or emulsifying aids
8. Fillers to give strength, body, or other properties to the material.

Available Materials

Materials that are available and have been used both in industry and the water industry are polyethylene, cellulose acetate butyrate, polyvinyl chloride (PVC), and rubber-modified polystyrene.

Commercial pipes are produced in sizes ranging up to 12 in. and in length up to 30 ft, and numerous stock fittings are also available. The materials listed above have been extensively used in industry for the transmission of oil, gas, water, acids, alkalis, salt solutions, alcohols, and many other corrosive chemicals.

Plastic water service lines have been installed from the East Coast to Kansas since World War II. Reports from the West Coast (*2*) show that the use of plastic pipe for service connections has been under study and many connections have already been installed. Numerous irrigation systems in the West and Southwest have been using plastic pipe. Many swimming-pool builders are currently using plastic tubing. The Navy is spending large sums on washdown systems to eliminate radioactive fallout contamination in warships. Plastic pipe (high-impact PVC) was selected because of its resistance to fire, corrosion, weathering, and because of its flexibility.

Reports from some early installations indicate complete suitability for the job and a considerable saving in cost. Others report complete failure and list causes such as rupture, brittleness, shrinking, and the imparting of taste and odors to the water. Studies have indicated that failures were caused by a lack of engineering understanding of the materials used. Available data indicate that many of these failures are traceable to a lack of satisfactory engineering design or to poor installation techniques. With increased knowledge of plastics and with better controls by the industry to produce a more uniform product, many recent installations are giving satisfactory performance and at considerable savings.

Los Angeles (*3*) has used plastic pipe on an experimental basis since 1951. Thorough tests have been made

with polyethylene and cellulose acetate butyrate tubings, and they are considered unsatisfactory. Attention in Los Angeles has centered on rigid, polyvinyl chloride tubing. Pilot installations have been made in 1-in. size and are being used with pressures ranging from 45 to 150 psi. The current procedure for jointing the tubing is to use a common type of reaming tool to provide an inside chamfer on the female end of the pipe, and an outside chamfer on the male end of the pipe to be joined to it. The end of the pipe to be belled is heated by a soft flame from a butane torch or a plumber's torch until it becomes soft. Meanwhile, liquid plastic solvent is applied to the end of the cold piece of pipe. Then the ends are butted together and pressure applied. The chamfered ends center the tubing and the cold end becomes the forming tool. The unheated pipe is inserted, without the use of any spreading tool, to a depth of 2 in. As the joint cools, contraction and the solvent form a tight joint. This operation takes less than a minute. Long-radius bends for risers to meters are made by inserting a flexible, metal conduit in the pipe to provide interior support and prevent collapse or buckling. Then the pipe is heated throughout the length of the bend using a butane torch, and in one movement the bend is made. The flexible tubing is then removed immediately. Skilled workmen may perform this operation in about a minute. Repairs to damaged service connections are made by covering the damaged section with a sleeve. The sleeve is softened by heating and slipped over the damaged section, which has been covered with a solvent cement. The repair sleeve is held in place for a few seconds to allow the solvent to weld it to the pipe.

Los Angeles reports considerable savings in the cost of installing polyvinyl chloride tubing as compared to copper tubing, but also recommends certain precautionary measures:

1. Because plastic tubing cannot be located by conventional electronic pipe locators, accurate records are necessary.

2. If plastic pipe is used for house connections as well as utility service connections, some problems of electrical grounding may be encountered, depending upon soil conditions.

3. Bends should be made only after heating to secure permanent set without strain.

The Los Angeles Department of Water and Power reports that it has not adopted plastic tubing for universal use, but that it is expected that experience will lead to its wider use.

The manufacturers of plastic pipe make the following claims regarding its characteristics: It weighs approximately one-fourth as much as steel pipe, is resistant to corrosion and aging, will not support combustion, has good insulating properties, is resistant to abrasion, imparts no taste or odors to the water, and has a low installation cost.

These claims are substantiated by industries that have used this material extensively, but these industries, together with the producers, also recommend that the following things be considered both in design and installation to insure adequate performance:

1. This material has a high coefficient of expansion and temperature variations should be considered. Expansion joints, return bends, or snaking the pipe in the trench is recommended.

2. The tensile strength of plastic is materially affected by temperature and the manufacturers' recommendations should be followed regarding allowable temperatures and pressures.

3. The manufacturers' recommendations as to "effective tensile strength" should be used to prevent failure by creep.

4. Proper bedding should be provided.

5. Proper backfilling procedures should be observed to prevent damage to pipe during installation.

Tests

Because of the natural caution of public health officials in permitting the use of new and untried materials for conveying public drinking water, a study of the suitability of plastic pipe for potable water supplies has been conducted by the National Sanitation Foundation (*4*). This foundation has its headquarters at the University of Michigan and is a nonprofit, noncommercial organization. This study was sponsored by the plastics industry with an advisory committee consisting of one representative from AWWA, five members representing state departments of public health, and five members representing manufacturers. These studies were carried on for 3 years using 22 samples of plastic pipe, including polyethylene, cellulose acetate butyrate, polyvinyl chloride, and polystyrene. The purpose of the study was to determine the suitability of these materials for underground use in conducting cold potable water. A partial summary of the report indicates the following:

1. Samples of plastic pipe exposed to natural weathering for a period of a year under standardized conditions showed only slight changes.

2. Burying samples in acid soil of pH 2.0 and holding them at 35°C for a year, with intermittent wetting and drying, showed very little effect on any of the test plastics.

3. Plastic pipe that was partially immersed in test water for a year at 35°C showed only slight color change, slight film formation, and in some cases a slight fungus growth.

4. Extraction tests showed that it was impossible to extract any deleterious substances from test samples that were recommended for domestic water use.

5. Taste and odor studies showed no greater intensity of odors in any of the water samples that had been exposed to plastic pipe than in the controls.

6. In determining the effect of plastic pipe on chlorine residuals, it was found that in no instance was the reduction in free chlorine residual so rapid as to materially change the effectiveness of the chlorination of drinking water.

7. Tests showed that plastic pipe can be satisfactorily disinfected by following standard disinfection procedures.

8. Rats given water that had been in prolonged contact with plastic pipes showed no appreciable abnormal effects as compared to the control group.

9. Plastic pipe was susceptible to rodent attack when the pipe obstructed access to food. There was no evidence that rats ate the plastic or gnawed it in preference to other materials.

Conclusions

Because of certain physical characteristics of plastic pipe as well as its low cost, whereas the cost of metal pipe is always rising, plastic tubing is now being considered more favorably. It is recognized that although price is not the sole index of suitability, it must certainly be considered. Through improved production techniques, plastic pipe is now being produced under

better controls, and there is now more standardization of dimensions and closer tolerances. More important, however, is the accumulation of knowledge of the characteristics, applications, and limitations of the material. Although plastics will never completely replace copper, iron, steel, or aluminum, they are no longer the mere substitutes they once were. It has been predicted that plastic pipe will soon capture 15 per cent of the metal pipe market. Plastics have a long way to go before they are completely accepted, but they are well on their way and there can be no doubt that they are here to stay.

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Progress Report—*Bert S. Montell*

A paper presented on May 16, 1958, at the Pacific Northwest Section Meeting, Spokane, Wash., by Bert S. Montell, Secy., Thermoplastics Pipe Div., Society of the Plastics Industry, Inc., New York, N.Y.

ALTHOUGH the general public considers plastic a new piping material, plastic pipe was actually produced as early as 1940, when it was used in the chemical and food-processing industries.

It was in 1941 that the Southern California Gas Company of Los Angeles initially installed butyrate pipe as distribution lines for natural gas in the metropolitan area of the city of Los Angeles. Since that time many thousands of feet of plastic pipe have been used by the utilities in service lines for the distribution of natural gas.

A survey of 30 distribution companies reveals that they plan to use approximately 800,000 ft of plastic pipe for operational installations during 1958. It is anticipated that a 35 per cent increase in the use of plastic pipe for natural-gas distribution will be attained during this year.

During the past decade, since the introduction of polyethylene plastic pipe in 1948, an increasing amount of plastic pipe is being used in various types of water services, including jet wells, well-to-house piping, lawn-sprinkler systems, service lines, and in varied irrigational services.

It has been estimated that 1,500,000 separately owned water installations in the United States are using various types of plastic pipe. Its successful use for these diversified applications is convincing testimony that plastic pipe is a practical reality today and will give satisfactory service when installed on an engineering basis in accordance with the manufacturer's recommendations and operated within its pressure–temperature limitations.

In recent years there has also been a marked growth in the use of plastic pipe in the petroleum industry. The problem of corrosion resistance in transporting crude oil to distribution centers or refineries is one that has always plagued petroleum engineers.

Recognizing that plastic pipe had excellent corrosion resistance as well as physical properties that lower paraffin buildup, the oil companies have continued to use increasing amounts of these piping materials during the past several years.

With a severe corrosion problem to deal with, the mining industry has also turned to plastic pipe because of its high resistance to acids and alkalis. No galvanic or electrolytic action is encountered with plastic pipe, which makes it suitable for use in corrosive soil and water conditions.

The chemical industry, realizing the advantage of the corrosion resistance inherent in the plastic pipe, continues to turn to this product for high-hazard, specialized applications in transporting corrosive fluids. At the present time, however, approximately 75 per cent of the plastic pipe produced is used for conveying water (irrigation, sprinkling, and jet pumps).

Of the various types of plastic materials used in the manufacture of pipe, the principal raw materials are polyethylene (low, medium, and high density), cellulose acetate butyrate, polyvinyl chloride (PVC), and acrylonitrile-butadiene-styrene (ABS).

Polyethylene

Polyethylene material was first extruded into plastic pipe in 1948. The material itself is a derivative of ethylene gas, which is a component of natural gas. It may also be derived from petroleum during refining. The gas is solidified when put under pressures that exceed 20,000 psi.

Polyethylene has an interesting war record. It was originally developed in Great Britain on an experimental basis in 1940. Because the material has remarkable electrical properties, it was used in the construction of radar sets which were used to detect German planes flying across the English Channel. Owing to the superiority of British radar, which in turn depended upon polyethylene materials, the British antiaircraft was most effective in turning back the Luftwaffe and turning the tide of the Battle of Britain.

Everyone is familiar with polyethylene in housewares and squeeze bottles. Within the past several years a high-density polyethylene material manufactured by a catalytic process has been developed and is now being used satisfactorily in the manufacture of a semi-flexible plastic pipe for various uses.

Although at one time polyethylene materials were all very similar, this is certainly no longer the case. With new polymerization techniques, polyethylenes are made by both high- and low-pressure processes with a sp gr of 0.915–0.965. These materials vary from flexible to rigid, and have short-time tensile strengths of 1,200–4,000 psi.

At first, polyethylene pipe was rated by assuming a factor of safety, usually four, based on short-time burst. As a result of extensive testing by raw-material manufacturers, pipe extruders, and the Society of the Plastics Industry–sponsored Battelle Memorial Institute project, some of the pipes are now rated on the basis of creep rupture data rather than the previous basis. In practice, with compounds especially formulated for pipe, this has resulted in higher permissible fiber stresses with no sacrifice in service performance.

Certain pipe manufacturers are also extruding plastic pipe from a blend of low-density and high-density polyethylene materials. The flexible polyethylene pipe produced from the low-density or conventional materials is the pipe that still represents approximately

75 per cent of the total dollar market, however. This black flexible pipe is available in lengths ranging from 400-ft coils in the ½-in. size to 200-ft coils in the 2-in. size. It has high impact strength and is the lowest in cost of all types of plastic pipe, in addition to providing the greatest ease of installation. It is limited to relatively low pressure and an operating-temperature range of −65°F to +120°F. Because of its cold-flow characteristics and chemical inertness, it can neither be threaded nor solvent welded. The common method of joining flexible polyethylene pipe is with insert fittings and stainless-steel clamps.

Butyrate

Cellulose acetate butyrate is made of cellulose, acetic acid, and butyric acid. These ingredients are put together to make a plastic. Common uses of butyrate materials are color telephones and automobile steering wheels. Butyrate pipe is black, glossy, and semirigid. It has an operating-temperature range of −40°F to +140°F. Its principal uses have been in crude-oil–gathering lines, salt-water disposal lines, and in new and replacement natural gas service lines. One of its major advantages is its high resistance to paraffin buildup when used in petroleum lines. This pipe is generally joined by solvent welding with slip-sleeve fittings. At present butyrate pipe is not recommended for conveying potable water, as it may impart taste and odor.

Acrylonitrile-Butadiene-Styrene

Acrylonitrile, a colorless liquid, is one of the ingredients used in producing buna-type synthetic rubber. Butadiene and styrene are also used in producing certain types of synthetic rubber. These materials are derived from petroleum. Acrylonitrile, butadiene, and styrene, in combination, make a plastic that has numerous excellent chemical and physical characteristics. It is often made into camera and typewriter cases, as well as various types of luggage. Acrylonitrile-butadiene-styrene (ABS) pipe is noted for its heat stability, toughness, high impact strength and good chemical resistance. It is a relatively rigid pipe, furnished in either blue-gray or black, and has an operating temperature range of −40°F to +170°F. Its principal uses are in the chemical and food-processing industries, as gas transmission pipe to irrigation pumps, and in an increasing number of potable water and irrigation applications. It may be joined by either the conventional threaded connection or solvent welding with slip-sleeve fittings.

Polyvinyl Chloride

Polyvinyl chloride materials may be produced from acetylene. Acetylene gas can be manufactured by treating calcium carbide electrolytically. Today, however, owing to the demand, this gas, and in turn, these materials, are made from petroleum.

These materials are extensively used as insulation on wire, where, to a large extent, they have supplanted natural rubber. In sheet form, they are made into hoods and ducts for use in industrial and chemical plant ventilating systems where corrosion is a constant problem.

Polyvinyl chloride (PVC) pipe is very rigid, gray in color, and has an operating temperature range of −40° to +160°F. Its principal uses follow those of butyrate and ABS pipe, but it is most widely used in the chemical and food-processing industries. PVC pipe

has one of the highest tensile strengths among the thermoplastic pipes. It is known for its good dimensional stability and its outstanding weathering properties. The German chemical industry has been using PVC pipe for over 20 years in places where corrosion is a problem. At the present time, increasing quantities of light-weight PVC pipe are being used on the West Coast, particularly in cold-water distribution services and in irrigation.

All of these classes of plastic pipe are available in iron-pipe sizes in the various schedules. Some of these classes area also available in solvent-welded–pipe (SWP) sizes. Some of the extruders in the industry adopted these SWP sizes to insure that this pipe would be joined by solvent welding rather than threading.

When the plastic-pipe industry started to expand after World War II, the manufacturers recognized the need for an organization. They moved to establish the Thermoplastics Pipe Division within the framework of the Society of the Plastics Industry, Inc. (SPI), which serves as the technical and trade association for the plastics industry. Initially, the pipe and fittings manufacturers undertook to establish dimensional and, ultimately, performance standards on each major class of plastic pipe. They began cooperative research to develop suitable test methods, and established an effective liaison with other associations representing users and potential consumers of plastic pipe.

The Thermoplastics Pipe Division has since established a coordinated relationship with such organizations as AWWA, the American Gas Association, the American Petroleum Institute, the American Society of Sanitary Engineering, ASA, ASTM, and various interested plumbing organizations throughout the country.

Dairy farmers in the Middle West were among the first to use plastic pipe. They were followed closely by many rural and suburban communities, and, as the pipe came to be used extensively in rural and suburban areas, the public health officials concerned with the water supply in these areas gave their attention to the new material. They raised the question of whether any independent research laboratory had evaluated the suitability of plastic pipe for drinking-water service. Although the companies that supply basic plastics materials knew that their materials were suitable for such service, no research had, in fact, been undertaken by an independent laboratory. At the suggestion of public health officials, the thermoplastic-pipe manufacturers were encouraged to foster a research project to determine the suitability of their product for transportation of potable water. As the National Sanitation Foundation, which is affiliated with the School of Public Health at the University of Michigan, had conducted much research related to this subject, at the instigation of the public health officials, a research project was initiated at the National Sanitation Foundation by the Thermoplastics Pipe Division. This research was inaugurated in 1951 and concluded in 1955. These tests clearly demonstrated that properly formulated plastics, meeting the requirements established by the National Sanitation Foundation, were entirely suitable for use in drinking-water services. Today, the National Sanitation Foundation authorizes the use of its seal on plastic pipe intended for water service when such pipe meets certain rigid requirements. The seal of the National Sani-

tation Foundation on plastic pipe is the consumers' assurance that the pipe meets the rigid requirements for drinking-water services.

Standards

As the plastic-pipe industry has grown, the need for standards has become increasingly apparent. Programs were initiated several years ago to establish standards. Some standards have already been established. A dimensional standard on polyethylene pipe was first established in 1954 under the procedures of the Commodity Standards Division of the US Dept. of Commerce. Later, this standard was amended to incorporate performance requirements. It was republished in 1957. It is known as Commercial Standard 197-57. During 1957, dimensional standards were established on SWP butyrate and iron-pipe standard PVC pipe. These dimensional standards are known as CS206-57 and CS207-57, respectively. At present, the Thermoplastics Pipe Division is completing the development of material and performance requirements to be included in the polyvinyl chloride pipe standard. Meanwhile, a dimensional and performance standard on ABS pipe is being prepared by division members for eventual establishment as a US Dept. of Commerce standard. Simultaneously, all these standards are being processed through the ASTM and ASA for eventual establishment by those agencies as official American standards.

As a further demonstration of the foresight of the plastic-pipe and fittings manufacturers, a 4-year test research program was undertaken at Battelle Memorial Institute, Columbus, Ohio. This program is now going forward. The goal of this research project is to develop additional test methods that a plastic pipe manufacturer may use for measuring the service performance of the pipe he produces.

The subject of codes is undoubtedly of interest to most water utility men. As most of the plumbing codes were adopted years ago, they make provision only for the traditional types of pipe. It has been necessary, therefore, for the industry to give counsel to code-making authorities at the state and municipal levels in various parts of the country on how the codes should be modified to make provision for plastic pipe where it may be used appropriately.

Considerable research is being devoted to the development of new plastic materials. With the commercial production of these materials, the plastic-pipe manufacturers will test them, and, if they are found suitable, will adopt them as piping materials. Increasingly wide acceptance of plastic pipe in states and municipalities throughout the country, indicates a plastic pipe market of $75,000,000 at consumer level by 1960.

AWWA recently approved the formation of a committee within its organization to deal specifically with plastic-pipe matters. The plastic pipe industry hopes to be able to coordinate its standards activities with this AWWA committee with a view toward eventually promulgating AWWA standards on plastic pipe for conveying potable water.

Use in Skagit County, Wash.—*Fred J. Ovenell*

A paper presented on May 16, 1958, at the Pacific Northwest Section Meeting, Spokane, Wash., by Fred J. Ovenell, Mgr., Public Utility Dist. No. 1, Skagit County, Mount Vernon, Wash.

The Public Utility District of Skagit County, Wash., serves some 7,000 customers, both urban and suburban, in the more populous areas of Skagit Valley. Because the area is very extensive, over 210 mi of supply, transmission, and distribution mains are involved. By pipeline or highway, it is 20 mi east and west and 11 mi north and south.

Of the total mains in service, nearly 70 per cent have been installed as replacements or extensions by the district since the system was purchased late in 1939. The present pipelines, exclusive of service lines, are 34.5 per cent wood stave, 28 per cent asbestos-cement, 14 per cent galvanized iron, 8 per cent steel, 6 per cent cast iron, limited footages of concrete cylinder and copper, and 6.4 per cent plastic.

This 6.4 per cent represents 13.5 mi of semirigid acrylonitrile copolymer plastic pipe.

In addition to the semirigid plastic used in the smaller main installations, the district has some 10 mi of ¾-in. polyethylene in the plant as service lines to meters. Actually the polyethylene tubing was used first in October 1952, whereas the use of the semirigid pipe was not started until December 1953.

Polyethylene Pipe

Although the semirigid plastic pipe for smaller mains is the main subject of this article, some remarks on experiences with the polyethylene tubing are in order.

Polyethylene was first considered for service because of its ease of handling, resistance to corrosion, good carrying qualities, and, of course, its low cost compared with copper, which was being used at the time.

Being cautious, as most water utility people are, Skagit County personnel wished to exercise the utmost care in experimentation. Following the example of others who had used plastic pipe, they used the extra-heavy tubing, thus providing adequate safety margin, and used brass fittings at points of possible stress, such as the coupling connecting the corporation cock with the tubing. They also at an early date standardized on the use of the all-stainless-steel clamp (including the screw) as essential to a lasting installation in all kinds of soils.

Since pressures range from 45 to 90 psi, a lighter-weight tubing might have been used. The pipe used, however, is designed for a safe working pressure of 125 psi. This fact may account for the success thus far, inasmuch as there is a sizeable margin of safety in the wall thickness. Because polyethylene is a relatively new product, it was felt that it would be wise to reduce risks to the minimum by installing the strongest tubing available. Even this higher-quality pipe costs about one-third as much as copper tubing, and savings are very substantial.

In reviewing the experiences at Suburban Water Systems, Puente, Calif., related by Yackey (*1*), it is felt that they may have used overly light-

weight tubing for the job. He says that although the recommended maximum pressures were lower than system requirements, the calculated burst pressures and material test pressures were considered to provide ample margins of safety. From the author's experience, he would be inclined to believe this to be the source of the difficulties. On the other hand, Skagit County has used tubing of much greater strength than appeared to be necessary, and failures have been practically nil.

Problem of 2-in. Pipe

In larger city systems, the need for 2-in. water mains is not great, since sizeable mains for fire protection are a must. Although considerations for fire protection are always important in smaller cities, there is still need for 2-in. lines in many locations, and in rural areas, where fire protection mains are often impractical, sizeable footages of such pipe are employed. In Skagit County's widespread system there are some 40 mi of 2-in. pipe of five different kinds: cast iron, galvanized, asbestos-cement, wood, and semirigid plastic. Of this over 31 per cent is galvanized, 28 per cent wood stave, nearly 13 per cent asbestos-cement, 1 per cent cast iron and 27 per cent plastic.

Skagit County has sought the 2-in. pipe with the fewest disadvantages. Cast iron, if cement lined, is fine, but it is costly to buy and install. The problems of corrosion and tuberculation in galvanized pipe reduce its effective life as an efficient carrier of water. Wood-stave pipe maintains good flow characteristics but has a limited life, particularly where the wire-winding is adversely affected by soil conditions. Asbestos-cement pipe is no longer made in 2-in. size. Unsatisfactory experiences with this pipe in this size indicate that the manufacturers found difficulty in fabricating a good 2-in. product. On the other hand, experiences with the larger sizes of asbestos-cement pipe have been satisfactory.

Semirigid Pipe

The district's unqualified success in the use of the polyethylene tubing caused a great interest in the development of 2-in. plastic pipe. The 2-in. polyethylene tubing, however, was found to be designed for relatively low head conditions and was high in cost. The answers to these objections seem to come with the advent of semirigid pipe. This material carried claims of greater tensile and impact strength along with the qualities of ease of handling, excellent flow characteristics, and economical cost.

The first semirigid pipe came in nominal sizes rather than iron pipe sizes, came in 20-ft lengths, and was joined by means of gray molded couplings. At the present time the district uses only iron pipe sizes (OD) in lengths of 25 ft joined with special-run, black-sleeve stock, cemented to each length at the factory. This size greatly reduces the problems of adapting to valves and fittings and provides some added carrying capacity owing to the thinner walls of plastic pipe. Standard flexible couplings and even brass or galvanized fittings can be used, if necessary. This creates few headaches for the storekeeper.

The 25-ft length reduces by 20 per cent the labor of coupling the pipe together, and at this length the pipe is

still easily handled and carted upon racks on top of the pickup trucks.

While gray, molded fittings are most widely used, and can be fabricated to closer tolerances, they are more costly and slow up the pipe assembly. Since the molded material is of much greater density, more acetone and time are required to break it down for the welding process. If a workman fails to remove the excess solvent, the continuing action of the acetone will weaken the wall of the pipe and cause failure under pressure.

The black-sleeve stock, although it is more difficult for the extruder to make to exacting dimensions, is simpler and faster for the workmen to put together. There is also a saving in the cost.

Perhaps the biggest obstacle encountered with this kind of pipe was that of tapping the line once it was installed. Saddles can be welded on, of course. This takes time because the welding action is slow. Full-circle service clamps appeared to be the answer, but those available would cause the pipe to be "out-of-round" when cinched up, thus rendering a tight seal impossible. Finally the district storekeeper came up with a design for a brass service clamp that does the job. It is easily and quickly installed and is permanent. Although wet taps have been made under pressure, the usual practice is to close down the branch line for a few moments as the tap is made.

Conclusions

There are obvious disadvantages to use of plastic piping. Since it is nonmetallic, and cannot be located with a pipe finder, it is necessary that map records be accurate and complete. Inasmuch as such maps are essential to good water utility practice anyway, the district carefully surveys all installations of pipelines, both new extensions and replacements, and checks to see that the actual system conforms to the proposed plan. Any deviations are noted and recorded on maps which are kept up to date. Under such a system the location of pipes is not a serious problem.

Plastic pipe cannot be thawed, if frozen. This makes it imperative that adequate coverage be maintained in all installations. Although damage from improperly installed hot-water tanks discharging hot water into the main during line shutdowns appears to be a possible hazard, to the author's knowledge this has not yet happened.

No doubt all users of plastic pipe are agreed that much remains to be done within the industry to set up needed controls and standards with adequate identification markings to assure the user of the quality of the product he is receiving. It is to be hoped that standardization within the plastics industry will be achieved at an early date to eliminate confusion and misunderstanding. No doubt AWWA representation on ASA Committee B16 will actively assist in bringing about these desired improvements.

Great strides have been made, however, and it has been demonstrated that the suppliers and extruders are anxious to determine the water industry's needs and problems, as well as cooperate in finding solutions. After all, a great many water systems need every help available in an effort to keep costs at a minimum in these days of constantly rising material prices and wages. A large percentage of water utility

expenditure is for pipe. If a permanent pipe can be secured—one that is easily installed, corrosion resistant, and has good carrying qualities—at a substantial saving in dollars, the water industry would be interested. These are the claims made for plastic pipe. From the author's rather limited experience, it appears that these claims may very well be substantiated.

Reference

1. YACKEY, H. H. California Experience with Plastic Pipe. *Jour. AWWA*, **48**:388 (Apr. 1956).

Use in Canada—*William Hewat*

A paper presented on May 16, 1958, at the Pacific Northwest Section Meeting, Spokane, Wash., by William Hewat, Naugatuck Chemical Co., Vancouver, B.C.

In Canada there are three manufacturers of raw materials for approximately sixteen extruders of plastic pipe. In 1958, 7,000,000 lb of plastic went into pipe, which is in the neighborhood of 28,000,000 ft of 1-in. pipe. A breakdown of the uses of this 5,000 mi of pipe shows that the majority of uses are similar to those in the United States.

Farmers are burying great quantities of plastic pipe for distributing water from wells to different parts of the farm, for jet wells, and for irrigation projects. Cottages are using plastic pipe for fresh-water supply and to carry sewage to its place of disposal. Golf courses and parks are laying plastic pipe for sprinkler systems. There are four such installations on golf courses in Vancouver. The history of some of these runs back as far as 4 years, and more are being planned for 1958, two in Vancouver. Some municipalities have replaced steel pipe with plastic pipe in mains and main-to-house connections. They are: Frelighburg, Que.; Dunneville, Ont.; Royston, on Vancouver Island; St. Williams, Ont.; and Haney, B.C.

A small community on Vancouver Island had a problem of transporting good water supply from across the bay. It was miles around the bay, or yards straight across. After the situation had been studied, 2,640 ft of 6-in. pipe was laid under the bay and anchored to the bottom with cement blocks. This has proved to be very successful.

A new use that will take a considerable number of miles of pipe in Canada is keeping logging ponds, hydro projects, and seaways ice-free and open during temperatures well below freezing. The federal government is studying a program to keep the St. Lawrence Seaway, from the Gulf of St. Lawrence to the lakehead, open the year round. The findings have not been made public, but the author understands that if plastic pipe were used, the project would require an investment of from 1–2 million dollars, $800,000 of which would be the cost of pipe and compressor stations. At this rate the project would not take too long to pay for itself, particularly with year-round shipping on northern inland waters.

Another interesting project of the same nature is the waterway between Athabaska tar-sands and Fort MacMurray, a distance of 50 mi. A highway in this area could cost as much

at $1,000,000 per mile. It is planned to run plastic pipe on the bottom of the channel in order to keep the waterways open during the long winter seasons, at a total cost of $250,000–$300,000.

Another use for plastic pipe that is rapidly growing and is of interest to the public-utility engineer is conduits, especially underground. The trend is from overhead to underground power transmission, because overhead lines are unsightly and are susceptible to ice and wind damage. Plastic pipe is a natural choice, because it has few joints, low coefficient of friction, flexibility, allows for snaking around obstacles in ditching, and makes possible easy corner bends. It is simple to remove old lines and install new ones. Engineers have testified that plastic pipe is quick and economical to install and satisfactory in service. The price is approximately one-third that of galvanized conduit.

For example, in the West, Calgary installed 2-in. plastic pipe in concrete for street and railway underpasses. This was in 1954. It was so successful that a further 20,000 ft was installed to carry all underground electrical cable to a complete subdivision. The 2-in. pipe protects primary cable that carries 2,300–4,160 v.

Edmonton installed 30,000 ft of conduit in 1956. Using unskilled labor, three men laid and joined 1,000 ft an hour. Edmonton has just purchased another 35,000 ft and is accepting bids for another similar amount.

Plastic pipe is finding an ever-widening use in the oil and gas industry. In the oil fields plastic pipe is being used for carrying crudes and in salt-water disposal systems. Natural-gas systems are making use of plastic pipe in the field. The latest is the Pembina gas-gathering system in Alberta. This system carries the gas from the different producing wells to the purifying and refrigeration system. Plastic pipe is also being used to carry natural gas from the main to consumers. The Alberta Gas Protection Branch has approved the use of semi-rigid plastic pipe of a type. This is for natural gas only, but it is a step in the right direction.

In Canada 5,000,000 lb of plastic went into pipe in 1956. In 1957, 7,000,000 lb was consumed. For 1960 it is difficult to forecast, but the plastics industry is predicting an even greater growth curve. The reasons for the growth prediction are:

1. The industries and people who consume pipe will become more and more aware of where and how they can take advantage of the economies of properly installed plastic pipe applications. As the history of each type of application grows, the public will accept plastic pipe more and more.

2. As research and development on present raw materials and new materials progress, plastic pipe will branch out into many new fields, for instance, the high-density linear polyethylene, which is currently being developed and evaluated. Pipe made from high-density resins, for the same wall thickness, has at least twice the burst strength at room temperature as low-density polyethylene pipe. It has much better creep resistance and a higher melting point. It would appear that high-density material will be suitable in the large-pipe field. Low density polyethylene, at present, is uneconomical in this field because of the excessive wall thickness required.

Another new resin receiving considerable attention is polypropylene,

but not enough is known about it to make any prediction.

Naugatuck Chemical, a division of US Rubber Co., has developed a new pipe compound. This new high-temperature high-tensile plastic will allow much higher operating pressures for the same wall thickness as present-day resins. This higher working pressure may also be obtained at high temperatures. For example, pipes of ½ in. to 2 in. will take temperatures of 212°F at 150 psi. This new compound in pipe could well be used in household plumbing.

Other raw-material suppliers are out to improve their compounds to give higher strengths at both low and elevated temperatures.

Plastic-pipe consumption will have a sharp growth curve owing to recognition of the merits of the present-day pipe and the new fields which will open as the new developments come along.

At present, there is a Canadian government specification (41GP-5) for polyethylene; it is an excellent document. Members of the National Building Code, SPI and the National Research Council are developing standards for PVC and butyrate pipe based on work done by National Sanitation Foundation and Battelle Memorial Institute. No doubt, these standards will be as complete and far-reaching as those for polyethylene. These specifications are only documentary; to be of any great benefit they should be set out in local building and plumbing codes in order to prevent misapplications owing to a lack of knowledge of specifications, and protect the public by putting a control on quality.

Status of Plastic Pipe for Water Service at Cleveland

The Cleveland, Ohio, Board of Building Standards & Building Appeals issued a report in February 1958 recommending the approval of a specific brand of plastic pipe for use in corrosive-waste piping and underground water service lines. As of Sep. 30, 1958, however, the Cleveland Division of Water & Heat had not authorized or approved the use of any kind of plastic pipe for water service connections in that city.

Generation and Use of Chlorine Dioxide in Water Treatment

Marvin L. Granstrom and G. Fred Lee

A paper presented on Apr. 23, 1958, at the Annual Conference, Dallas, Tex., by Marvin L. Granstrom, Chairman, Dept. of Civ. Eng., Rutgers Univ., New Brunswick, N.J., and G. Fred Lee, Research Asst., Dept. of San Eng., School of Public Health, Univ. of North Carolina, Chapel Hill N.C. This research was supported in part by a grant from the National Institutes of Health, USPHS, Washington, D.C.

THE results of a questionnaire survey indicate that in many instances the superintendents and operators of water plants in which chlorine dioxide is used are not fully aware of the optimum conditions that could be established for its generation; there was some lack of clarity on methods of measurement and on the purpose of chlorine dioxide; and there appeared to be some variation of opinion on the best points at which to apply chlorine dioxide or chlorine.

It is the purpose of this paper to present the results of the questionnaire survey and to discuss the methods and results of the research conducted in the Department of Sanitary Engineering at the University of North Carolina, and to suggest procedures for the generation of chlorine dioxide and for measuring the concentration of several chlorine compounds.

Questionnaire Results

A one-page questionnaire was mailed to 150 different water utilities that were believed to be using chlorine dioxide in treatment; there were 75 replies. A resume of the replies is given below:

1. The dates of inception of the use of chlorine dioxide ranged from 1944 to the present.

2. Nineteen of the 75 replies indicated that chlorine dioxide had never been used, or that its use had been discontinued. The reasons given for discontinuance were: "it didn't work out," "no need," or "high cost."

3. Thirty-four plants use chlorine dioxide all year long, and the other 22 use it intermittently.

4. The reasons for using chlorine dioxide given by different water plants were:

a. Fifty-two have problems of taste and odor; of these, 37 are phenolic problems.

b. Three have problems of iron and manganese.

c. Seven have algae problems.

d. Fifteen use it specifically for disinfection.

5. The points of application are: in raw water in fifteen plants, after coagulation in three, after settling in six, and after filtration in 35.

6. In 41 places, chlorine is added before or after chlorine dioxide—before in 34 instances and after in seven.

7. The quantity of sodium chlorite used in the generation of chlorine dioxide varied from 0.3 to 10 lb/mil gal and the quantities of chlorine used in the generation varied from 0.6 to 50 lb/mil gal. Ratios of chlorine to sodium chlorite varied from 10:0 to 1:1 (the $NaClO_2$ is assumed to be 78 per cent grade).

8. Only 25 replies indicated any pH measurement on solutions. The pH values of the sodium chlorite solution entering the generator varied from 8.7 to 12.55, although one value was given as 3.0 and another as 3.5. These latter two were either in error or pH adjustment of the chlorite solution had been made. The pH value of chlorine solution entering the generator (all chlorine used was gaseous) varied from 1.2 to 4.1; one value was given as 10.2 and pH adjustment was specified. The pH of the generator effluent varied from 1.2 to 10.4 and all but two values were 4.0 or less.

9. The contact time between the chlorite and chlorine before entering the water supply varied from 10 sec to 30 min, and most periods were less than 5 min.

10. The alkalinity of the final plant effluent varied from 4 to 200 ppm and the pH varied from 6.6 to 10.4.

11. Of the analytical methods used:

a. Twenty-nine plants specified the orthotolidine test, and of these eleven specified the orthotolidine–oxalic acid method.

b. One used the tyrosine method.

c. Four used the amperometric method.

d. Two used the starch–iodide method.

e. Twenty plants did not use analytical measurements on any of the molecular species.

Twenty plants were satisfied with analytical procedures and eleven were not; the remainder made no comment. These tests and others will be discussed later.

12. The final values of chlorine and chlorine dioxide concentrations in the water supply were given as follows:

a. Thirty-six gave values for chlorine of from 0.15 to 2.0 ppm.

b. Twenty-two gave values for chlorine dioxide of from 0.01 to 2.3 ppm.

13. Typical comments given were:

a. Effective with problems of phenols

b. Not good for high phenols

c. Good residual in distribution systems

d. Good for general taste and odor problems

e. Not good for general taste and odor problems

f. Cost high

g. Tests for concentrations needed

h. Corrosive to structures.

The general impressions that the authors received from reading the returned questionnaires were that chlorine dioxide is usually satisfactory where problems of phenols exist, that many operators were not fully aware of the optimum conditions for generation or of the chemical reactions, and that many operators were not satisfied with the measurement procedures they used.

Nature of Research

To the authors' knowledge, the only method presently used by water utilities for the generation of chlorine dioxide is mixing aqueous solutions of chlorine and sodium chlorite. When consideration of pH enters in, as it must, the number of reactions becomes quite numerous. By limiting the pH range for study to that commonly used in water plants, and by ignoring the effect of slow reactions, it was possible to reduce the number of appropriate equations to six. These are:

$$Cl_2 + H_2O \rightleftarrows HOCl + H^+ + Cl^- \quad (1)$$
$$(K = 4.5 \times 10^{-4})$$

$$HOCl \rightleftarrows OCl^- + H^+ \quad (2)$$
$$(K = 3.3 \times 10^{-8})$$

$$HOCl + 2ClO_2^- \rightleftarrows 2ClO_2 + Cl^- + OH^- \quad (3)$$

$$HOCl + ClO_2^- \rightleftarrows ClO_3^- + Cl^- + H^- \quad (4)$$

$$ClO_2^- + H^+ \rightleftarrows HClO_2 \quad (5)$$
$$(K = 0.93 \times 10^3)$$

$$4HClO_2 \rightleftarrows 2ClO_2 + Cl^- + ClO_3^- + H_2O \quad (6)$$

By appropriate use of the equilibrium constants it can be shown that between pH values of 3.5–5.5 the reactions described by Eq 3 and 4 predominate. Above a pH of about 5.5 the dissociation described by Eq 2 becomes important and reduces the effective concentration of hypochlorous acid (*1*). Below a pH of 2.0 the chlorine (Cl_2) concentration becomes significant, Eq 1. Below a pH of about 3.5 the reactions described by Eq 5 and 6* become important (*2, 3*).

The purpose of this research was to determine the concentrations of the products of the reactions described above under conditions of relative concentrations of reactants and at various pH values, and determine the time necessary for completion of the overall reaction.

* Some research subsequent to the preparation of this paper indicates that the mechanism of the reaction described by Eq 6 may be as follows:

$$2HClO_2 \leftrightarrows HOCl + ClO_3^- + H^+$$

The hypochlorous acid then reacts with the chlorine in equilibrium with the chlorous acid.

Reagents and Equipment

The following reagents were used: analytical sodium chlorite, chlorine gas, Lecture Bottle †; hydroxylamine sulfate, 5015 ‡; sulfuric acid, cp; sodium sulfate, potassium iodide, sodium thiosulfate, sodium chloride, sodium hydroxide, silver nitrate, acetic acid, reagent grade; phenylarsene oxide solution, 1 ml = $\frac{1}{3}$ mg chlorine. Chlorine demand–free water was used in the preparation of all stock solutions and in all reaction solutions. Chlorine solutions were prepared by bubbling chlorine gas into water.

The following equipment was used: Beckman spectrophotometer § with ultraviolet attachments and 1-cm silica cell having ground-glass stoppers; potentiometers ‖ with a galvanometer; pH meter **; constant-temperature bath †† (all reaction temperatures were set at 25°C and cell contents in the spectrophotometer were maintained at that temperature by circulating water through the cell block); Patwin ‡‡ electric polarograph; and a Sargent §§ manual polarograph. Room temperature was maintained by a steam radiator and an air conditioner; further humidity removal was effected by a dehumdifier. Figure 1 shows some of the equipment used.

† A product of Olin Mathieson Chemical Corp., Baltimore, Md.

‡ A product of Matheson, Coleman & Bell Div., Matheson Co., Cincinnati, Ohio.

§ Model DU, a product of Beckman Instruments, Inc., Fullerton, Calif.

‖ Fisher Type S; a product of Fisher Scientific Co., Pittsburgh, Pa.

** Beckman Model G; a product of Beckman Instruments, Inc., Fullerton, Calif.

†† Model 9934, a product of A. H. Thomas Co., Philadelphia, Pa.

‡‡ Electro-Polarizer, Model R1; a product of Patwin Instruments, Patent Button Co., Waterbury, Conn.

§§ A product of E. H. Sargent Co., Chicago, Ill.

Generation of Chlorine Dioxide

Chlorine dioxide, used for calibration, was generated by two different combinations of reagents.

The first was from sodium chlorite and sulfuric acid, the overall reaction possibly being

$$4HClO_2 \rightarrow 2ClO_2 \uparrow + Cl^- + ClO_3^- + H_2O \quad . . (7)$$

procedure was to add either the sulfuric acid or potassium persulfate to the sodium chlorite solution; the chlorine dioxide generated was swept from the solution by using dry nitrogen gas. The column containing dry sodium chlorite was added to absorb any chlorine gas or volatilized hypochlorous acid; the vacant chamber was used to collect any sodium chlorite dust that

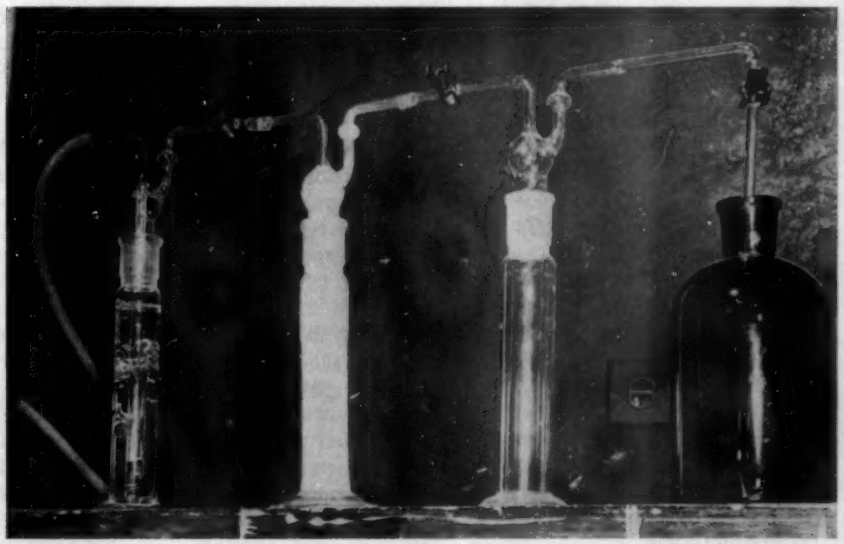

Fig. 1. Chlorine Dioxide Generator

The component parts of the generator shown above are, reading from left to right: reaction vessel; sodium chlorite column; dust trap; and collection vessel.

The second was from sodium chlorite and potassium persulfate, the overall reaction probably being

$$2ClO_2^- + K_2S_2O_8 \rightarrow 2ClO_2 \uparrow + 2K^+ + 2SO_4^{--} \quad . . (8)$$

Figure 2 is a photograph of the generator used. Ground-glass fittings were used in all instances to avoid contact with rubber or plastic. The might have been carried over; and the final collection was in water.

Following an initial flushing period, a 3×10^{-3} to $5 \times 10^{-3} M$ solution of chlorine dioxide was made in 15–20 min. This solution was diluted as desired. Because of the sensitivity of chlorine dioxide to light, all work involving its preparation or use was conducted in semidarkness. Storage was in complete darkness in dark bottles.

In the light, the rate of decomposition of chlorine dioxide was as high as 10 per cent per day, whereas with storage in a dark refrigerator the rate of decomposition was less than 1.0 per cent per week.

Measurements

One of the problems confronting the operator or research worker, when he attempts to analyze mixtures for concentrations of the various molecular species of oxychloro compounds, is measurement. This section includes a discussion of the measurement techniques used in this research. Ordinarily the equipment used in the research laboratory is not readily available to the plant operator, and suggested analytical methods for the water plant operator are therefore included.

Spectrophotometric Measurements

Spectrophotometric measurements of the type used in this research operate on the principle of absorption of radiant energy. Usually the amount of absorption depends upon the wavelength of the incident radiant energy. Substances differ in their ability to absorb particular wavelengths and the pattern of absorption as a function of wavelength for any one substance is its spectrum. Typical spectra of chlorine dioxide, chlorite, and hypochlorous acid are shown in Fig. 2. With the type of spectrophotometer used in this research it is possible to determine concentrations by observation of the percentage of the incident light absorbed at a given wavelength. The relationship of absorbance to concentration having been previously established by calibration of the instrument with solutions of known concentration, Figure 3 is an illustration of such calibration curves. The wavelength of incident energy usually selected for measurement is that of maximum absorbance. With such calibration curves it is possible to measure concentrations quite readily.

It is also possible to determine concentrations of mixtures of molecules or ions by taking several spectrophotometric readings and then using appropriate mathematical equations. Because of the rapidity with which one may take readings on a spectrophotometer (depending upon the design of the instrument), it is possible to trace changes of concentration of a single molecular species or mixtures of species. In this research the spectrophotometer was used to measure the concentration of chlorine dioxide, chlorite ions, and hypochlorous acid when they occurred singly or in combination.

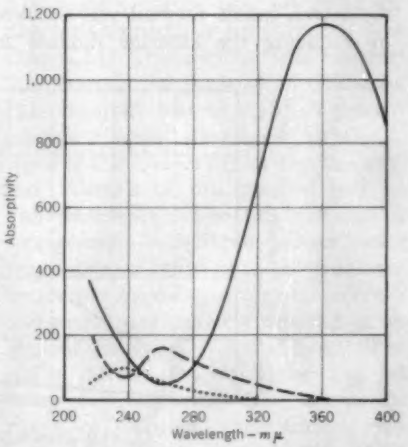

Fig. 2. Typical Spectra of ClO_2, ClO_2^-, and HOCl

The solid, dashed, and dotted curves represent typical spectra of chlorine dioxide, chlorite, and hypochlorous acid, respectively. All concentrations are considered constant.

Calibration Curves

Chlorine dioxide. Solutions were prepared in the manner described above. Absorbance readings were taken on several concentrations of at least twelve different solutions at 360 mμ, 260 mμ, and 235 mμ. Then the concentration of chlorine dioxide in each instance was determined by the starch–iodide procedure at pH 1.0–1.5 using thiosulfate (*4*). The accuracy of the starch–iodide method was checked by reducing the chlorine dioxide to chlorides, using 0.01*M* hydroxylamine sulfate, and then determining the chlorides in the manner described below. Unfortunately, absorption of ultraviolet radiant energy by chlorine dioxide does not follow Beer's Law at the 360-mμ wavelength; so a concentration–absorbance curve was prepared. At 260 mμ and 235 mμ the absorbance does follow Beer's Law. Figure 4 shows the relationship between chlorine dioxide concentration and absorbance at these three wavelengths.

Chlorite. Absorbance readings were taken at 360 mμ, 260 mμ, and 235 mμ for at least fifteen different concentrations of sodium chlorite solutions; the absorbance followed Beer's Law at all three wavelengths. The concentration of each solution was determined by the starch–iodide method at pH 1.0–1.5, using thiosulfate. The accuracy of this method was checked by reducing the chlorine dioxide to chlorides, using 0.01*M* hydroxylamine sulfate, and then determining the chlorides in the manner described below.

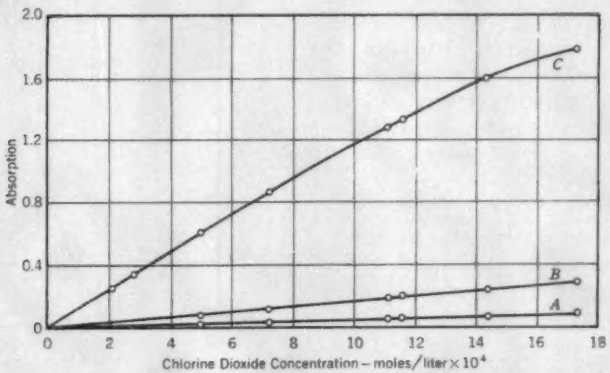

Fig. 3. Calibration Curves for Chlorine Dioxide

The three curves represent the relationship of absorption to chlorine dioxide concentration at three different wavelengths: Curve A—$\lambda = 260$ *mμ; Curve* B—$\lambda = 283.5$ *mμ; Curve* C—$\lambda = 360$ *mμ.*

From the value of the dissociation constant K, given below Eq 5, the ratio of chlorite to chlorous acid molar concentrations was calculated at various pH values. The results are shown in Table 1.

It is apparent that at pH values below 3.5 an increasingly large amount of the chlorite is converted to chlorous acid. Thus, spectrophotometric measurement of chlorite below a pH of about 3.5 is not practical. Because, according to Eq 6, chlorous acid is

TABLE 1

Molar Ratios of Chlorite to Chlorous Acid at Various pH Values

pH	Ratio
1.0	0.1
2.0	1.0
3.0	10.0
3.5	31.6
4.0	100.0
5.0	1,000.0
6.0	10,000.0

spontaneously converted to chlorine dioxide, a spectrum for chlorous acid could not be determined conveniently.

Hypochlorous acid. From the values of K given below Eq 1 and 2, it is possible to calculate the relative percentages of Cl_2, HOCl and OCl^- as a function of pH. An illustration of this is shown in Table 2.

It appears that the chlorine is in the form of hypochlorous acid at pH values of 2–5.5 and that the spectrophotometer could be used to measure the concentration of hypochlorous acid in that pH range. The authors were not satisfied with the results at pH values less than 3.5. No attempt was made to investigate the discrepancies noted.

In the manner described above, absorbance readings were taken on at least twelve different solutions of hypochlorous acid at 235 mμ, 260 mμ, and 360 mμ. Concentrations were determined by the starch–iodide method at the acetic acid–sodium acetate buffer pH range using thiosulfate (*5*).

Chloride Measurements

No satisfactory method was found for measuring chlorides in the presence of chlorites, hypochlorous acid, or chlorine dioxide, and total chlorides were therefore determined after reduction of these three substances with hydroxylamine sulfate (final concentration about 0.01M). Hydroxylamine sulfate does not reduce the chlorates at pH values above about 4.

Three different instrumental methods of analysis for chlorides were used. [1] The amperometric-titration technique, using $AgNO_3$ as described by Kolthoff and Lingane (*6*): In the presence of chlorates, the results seemed to be somewhat erratic, and this method was abandoned. [2] The potentiometric-titration technique, using silver and calomel electrodes with a potassium nitrate–agar bridge in the manner described by Kolthoff and Laitinen (*7*): This method was satisfactory even in the presence of chlorates, but was quite tedious. [3] A polarographic method developed by C. R. Spell of the University of North Carolina: Details of this method will be published soon. For this research it was possible to calibrate galvanometer readings as a function of chloride concentration by using dropping mercury and mercurous sulfate electrodes at an applied potential of −0.075 v. The pH of the solution was lowered to 1.0 using sulfuric acid. The acceptable range of chloride concentration was from 2.5×10^{-4} to $2.0 \times 10^{-3}M$. This method is very rapid and the results were reproducible within 2 per cent.

The chlorides in this mixture were from three sources: [1] the hydrolysis

TABLE 2

*Percentages of Cl_2, HOCl, and OCl^- at Various pH Values**

pH	Cl_2	HOCl	OCl^-
1	18	82.0	
2	1	99.0	
3		100.0	
4		100.0	
5		100.0	
6		96.8	3.2
7		75.2	24.8

* Total chlorine = $1 \times 10^{-3}M$.

of chlorine to form hypochlorous acid and chloride (Eq 1); [2] the reduction of chlorine dioxide, chlorite, and hypochlorous acid; and [3] chlorides formed during the various other reactions. The concentration from the third source was determined by subtracting the sum of the other two from the total concentration after the reduction step.

Chlorate Measurements

Chlorates could not be measured spectrophotometrically with the equipment available. The absorbance was very slight even at the shortest wavelengths attainable on the available instrument. The most practical procedure developed was to measure the chlorides attained after reduction of the chlorine dioxide, chlorites, and hypochlorous acid by one of the methods described above. Then, by use of a Jones reductor (*8*), the chlorates were reduced to chlorides and the increase in chlorides was attributed to the chlorates present.

Run Procedure

Two different types of run were made: [1] in the pH range 3.5–5.5, only spectrophotometric readings were necessary to determine concentrations of chlorine dioxide, chlorite, and hypochlorous acid; and [2] outside of the pH range 3.5–5.5, where the spectrophotometric readings were only useful for determination of the chlorine dioxide concentration, it was also necessary to use starch–iodide titration. For both types of run chloride and chlorate determinations were made at the completion of several runs.

To make an individual run, separate solutions of chlorine and chlorite of known molar concentrations, as measured by the spectrophotometer, were mixed rapidly. The beginning of the mixing period was designated as time zero. In order to assure a constant pH during the course of a reaction, a buffer system was used. For the reactions in the pH range 3.5–5.5 an acetic acid buffer was used; the pH adjustments were made using sulfuric acid or sodium hydroxide. The acetic acid concentration in the reaction solution was 0.01*M*. For the set of runs at pH 6.5, a phosphate buffer system of 0.01*M* was used. Measurements of pH were made near the beginning and at the end of each run. No attempt was made to control the ionic strength because there was no intent to make detailed analyses of reaction velocity coefficients, mechanisms of reactions, or activation energies. These studies will be conducted in future research.

A portion of the mixture of chlorine solutions with the buffer system and the chlorite was pipetted into one of the 1-cm silica cells, which was then inserted into the spectrophotometer. Frequent readings were taken at 360 mμ, 260 mμ, and 235 mμ in the runs with pH values between 3.5 and 5.5 and at just 360 mμ in the runs with pH values outside of this range. The blank cell contained all constituents of the reaction cell except chlorine and chlorite.

Calculations

For the runs with pH values outside the 3.5–5.5 range, only the chlorine dioxide concentrations were determined from the spectrophotometric readings taken at 360 mμ. At this wavelength, the absorptions due to hypochlorous acid, hypochlorite ion, chlorite, or chlorous acid were so small compared to the absorption due to chlorine dioxide that they could be ignored and

the chlorine dioxide determined directly from the concentration–absorbance curve shown in Fig. 3.

For the runs of pH value between 3.5 and 5.5, the chlorine dioxide concentration was determined as described in the preceding paragraph; however, it was also possible to trace the change in concentrations, with time, of hypochlorous acid and of chlorite.* The spectrophotometric data used in this report were taken when the reactions were complete. By assuming that the total absorbance at any wavelength is the algebraic sum of the absorbance of each of the molecular species present, it is possible to determine the concentration of the individual molecular species, providing that readings are taken (at a minimum) at the same number of different wavelength settings as there are molecular species present, and that the absorptivity of each molecular species at each of the wavelengths is known. (Absorptivity is the absorbance of a 1*M* solution.) The method for calculations for concentrations from such spectrophotometric readings is a standard procedure and will not be discussed herein. The final results are shown in Table 3.

As described above, it was possible to trace the change of chlorine dioxide concentration with time using the spectrophotometer only, for the runs in which the pH values were outside the range of 3.5–5.5. Measurements for hypochlorous acid–hypochlorite or for chlorite–chlorous acid were not readily accomplished outside this range. Theoretically this is possible, but there may have been as many as five overlapping spectra, and the accuracy of measurement under the conditions of this research is quite limited. Thus, as described above, the concentration of hypochlorous acid–hypochlorite or chlorite–chlorous acid was determined by subtracting the chlorine dioxide concentration from the total oxidizing capacity as determined by the starch–iodide method at pH 1–1.5. At this pH chlorates are not reduced and thus do not show oxidizing capacity. From previous experience, obtained from the runs conducted between pH 3.5 and 5.5, it was known what form the residual would take. From Table 3 it can be seen that when the molar ratio of chlorine to chlorite is less than 1:2 the final solution will contain chlorite and chlorine dioxide, and when the ratio is greater than this the final solution will contain hypochlorous acid and chlorine dioxide. Thus it was possible, using this combination of measurement procedures, to determine the final values of chlorine dioxide and chlorine or chlorite.

Following the completion of a run, the concentrations of chlorides and chlorates were determined or calculated. According to Taube and Dodgen (*9*), it may be assumed that the chlorite goes to chlorine dioxide, chlorate, and chloride and that the chlorine goes to chloride during the course of the reactions described by Eq 3, 4, and 6.

Experimental Results

As a result of the experimental data, it is possible to draw several conclusions regarding the rates and products to be expected with certain ratios of chlorine to chlorite in the reaction solution, the effects of pH values on

* Although there is no analysis of the kinetics of reactions, and no use was made in this report of the kinetic data obtained (except the completion time of the reactions forming chlorine dioxide) it may be of interest to mention that by collecting such data it would be possible to make such an analysis.

TABLE 3

Spectrophotometric Data on Reactions Forming Chlorine Dioxide

pH	HOCl*		ClO_2^{-}*		ClO_3		ClO_3^{-} Formed*	Completion Time *min*
	Initial	Final	Initial	Final	Formed*	Per Cent Yield†		
2.04	5	—	10	—	7.0	70	3.0	<1
	5	—	20	4.2	10.6	53	3.5	<1
	20	17.2	5	—	3.6	72	0.4	<1
3.55±0.1	5	—	11.8	0.5	8.5	72		6
	5	—	11.8	0.5	8.5	72		6
	5	—	10	—	7.4	74		4
	5	—	20	6.4	10.2	51		3
	5	—	50	32.6	12.9	26		2
	10	3.5	11.8	—	9.3	78		<1
	10	4.0	10	—	7.9	79		<1
	10	4.5	10	—	7.9	79		<1
	10	2.4	5	—	3.7	74		<1
	10	3.0	5	—	3.7	74		<1
3.77±0.08	5	—	10	—	7.3	73		4
	5	—	10	—	7.3	73		4
	5	—	20	4.1	11.1	55		10
	10	7.4	5	—	3.6	72		<1
	10	5.3	10	—	7.6	76		2
3.95±0.06	5	—	10	—	8.0	80	2.0	5
	5	—	20	7.2	11.6	58	2.5	8
	20	17.0	5	—	4.4	88	0.3	2
4.36±0.04	4.45	—	10	—	8.0	80		16
	4.45	—	20	7.7	10.2	51		18
	8.9	4.1	10	—	8.5	85		2
	8.9	6.6	5	—	4.1	82		3
5.00±0.02	4.72	—	10	—	8.5	85		60
	4.72	—	20	9.0	9.8	49		55
	9.44	3.5	10	—	8.9	89		8
	9.44	6.5	5	—	4.3	86		10
5.45±0.07	5	—	10	—	8.0	80	1.8	80
	4.82	—	20	7.4	9.8	49	2.0	100
	20	17.3	5	—	4.1	82	0.4	4
6.48±0.06	5	—	10	—	3.1	31		>180
	5	—	20	10.8	5.3	27		>180
	20	15.4	5	—	1.5	30		30

* In moles per liter × 10^6.
† Per unit ClO_2^{-}.

rates and products, and methods of measurement.

With a molar ratio of chlorine to chlorite of 1:2 the end products did not include either chlorine or chlorite, but only chlorine dioxide. At ratios less than 1:2 there was residual chlorite; because chlorite is relatively expensive this normally would not be a desirable state. At ratios greater than 1:2 there was chlorine in the residual; the desirability of this is dependent upon local conditions. Furthermore, an excess of chlorine in the reaction solution increased the rate of the reaction. These relationships are shown in Table 3.

A decrease in pH increased the rate of the reaction, as shown in Table 3. For example, with chlorine–chlorite concentrations of from 5×10^{-4} to $10 \times 10^{-4} M$, at pH 5 the time of completion was about 60 min, and at pH 2 it is less than 1 min. It may, however, be seen that under these conditions the yield of chlorine dioxide to chlorite was 0.85 at pH 5 and 0.70 at pH 2; thus, increasing the rate by lowering the pH resulted in a decrease in yield. At pH values greater than 5 the yield dropped off; this may have been due to one of two causes: either the reaction was not complete, as supposed, or equilibria between the reactants and the products were reached.

Validity of Reaction Equations

There was some question as to which of the various reactions described by Eq 1–6 were actually operative in the formation of chlorine dioxide that resulted from the mixing of chlorine and chlorite.

Total chlorine. When chlorine gas is dissolved in water (the source of chlorine for this research), according to Eq 1, one Cl^- will be formed with each HOCl. Total reduction of all chlorine species found in this research should give a chloride molar concentration equal to twice the initial hypochlorous acid concentration plus the initial molar concentration of the chlorite. At the end of a reaction all chlorine species were reduced to chlorides by use of the Jones reductor and the chlorides were determined in the manner described above. The results are shown in Table 4. The maximum difference observed was 2.5 per cent. Thus, it is shown that the above assumptions are correct and that the analytical procedures are quite accurate.

TABLE 4

*Comparison of Chlorides Obtained With Assumed Initial Concentrations**

HOCl	ClO_2^-	Cl^-	
		Calculated	Observed
5	10	20	19.5
5	10	20	19.7
5	20	30	29.5
10	10	30	30.6
10	5	25	25.9

* In moles per liter $\times 10^4$.

Total chlorates formed. On several samples chlorates were determined by the difference method described above. The values obtained are shown in Table 3. These results substantiate the assumption that there are three possible reactions by which chlorites are consumed; these are described by Eq 3, 4, and 6. The fact that hypochlorous acid is consumed validates Eq 3. The fact that chlorates are formed validates Eq 4 or 6, or both. If Eq 4 were not operative, that is,

if only Eq 6 were responsible for all of the chlorate formed, the amount of chlorite consumed, as indicated by the concentration of the chlorine dioxide formed, would be in some instances greater than that initially available, and in most other instances there would not be sufficient chlorite remaining after the reaction, according to Eq 6, to account for the consumption of hypochlorous acid. On the other hand, if Eq 6 were not operative, the sum of chlorates and chlorine dioxide formed would be essentially equal to the chlorite consumed. This is not always the case; in some instances a portion of the chlorite has gone to chloride, particularly at the lower pH values. The decrease in ratio of chlorine dioxide formed to chlorite consumed at decreased pH also lends credence to Eq 6.

Thus, even though it is impossible, at this time, to describe in detail the kinetics and mechanisms of the reactions described in Eq 3, 4 and 6, it seems reasonable to assume, under the conditions of the experiments described herein, that all three reactions proceed simultaneously. Some general statements may be made: that at reduced pH values Eq 6 becomes more dominant; that lowering pH values tends to increase the overall rate of the reaction; that with increasing ratios of chlorine to chlorite, Eq 6 becomes less important.

Conversion Factors

The measure of concentration of all of the described work above was in moles per liter. In sanitary engineering work most concentrations are expressed in terms of parts per million (ppm), or, using units of the metric system, milligrams per liter (mg/l). Furthermore, chlorine dioxide and chlorites are frequently expressed in terms of equivalent chlorine.

To convert from moles per liter chlorine dioxide to milligrams per liter of chlorine dioxide the following procedure is used.

$$\text{moles per liter} \times \text{molar weight} \times 1{,}000 = \text{milligrams per liter} \quad (9)$$

Substituting 67.45, the molar weight of ClO_2,

$$\text{mg/l } ClO_2 = 67.45 \times 10^3 \times \text{moles per liter} \quad (10)$$

Because the oxidizing capacity of chlorine dioxide is 2.5 times that of chlorine, to express milligrams per liter chlorine dioxide in terms of chlorine it is necessary to multiply the right-hand side of Eq 10 by 2.5. The equation then becomes

$$\text{mg/l } ClO_2 \text{ as } Cl_2 = 1.686 \times 10^5 \times \text{moles per liter } ClO_2 \quad (11)$$

The oxidizing capacity of chlorite is twice the oxidizing capacity of chlorine and to convert from moles per liter of chlorite to milligrams per liter chlorite in terms of chlorine Eq 12 may be used.

$$\text{mg/l } ClO_2^- \text{ as } Cl_2 = 1.349 \times 10^5 \times \text{moles per liter of } ClO_2^- \quad (12)$$

Methods for Water Utility Use

The authors were able to use a spectrophotometer with ultraviolet attachments for a large portion of the measurements taken in this study and found it to be excellent. This instrument is normally not available in water plants.

To measure concentrations of chlorite and chlorine separately as they enter the generator, the starch–iodide method using thiosulfate at pH 1.0–1.5

is recommended. Sulfuric acid may be used to lower the pH; it should be added to the potassium iodide solution. This method also measures, without differentiation, chlorine and total chlorine dioxide. It may be used as a check on the method described below.

For measurement of chlorine dioxide and chlorine, or only chlorine dioxide as it leaves the generator, or in the water supply, a method proposed by Post and Moore (*10*) is suggested. By this method it is possible to measure both chlorine and chlorine dioxide. For measurement of the latter only, it is only necessary to remove the effects of chlorine or chloramines. The method does not differentiate between chlorine dioxide and chlorites; however, from the results of the questionnaire, it may be assumed that in no instance was there any residual chlorite in the chlorine dioxide solution, that is, in every instance the molar ratio of chlorine to chlorite in the generator solution was greater than 1:2.

Several other analytical methods in use were listed above in the discussion of the results of the questionnaire: the amperometric titration, orthotolidine arsenite (OTA), orthotolidine–oxalic acid (OTO), and tyrosine methods.

The authors have studied the amperometric method developed by Haller and Listek (*11*) and found that one of the reactions upon which this method is based may be much slower than was believed. This is the reaction in which conversion of chlorine dioxide to chlorite and chlorate by raising the pH was proposed.

The OTA test (*4*) may be used if there is no need to differentiate between chlorine dioxide and chlorite or chlorine. Care must be exercised in adjusting the pH. Furthermore, the test has definite limitations because of the possibility of color formation by substances other than oxidizing forms of chlorine.

The OTO test (*12*) is an adaptation of the OTA test, and uses oxalic acid as an additional reagent. In addition to the limitations of the OTA test, the results of the OTO test for chlorine dioxide depend upon the multiplication of a difference value by a factor of five. This seriously limits the accuracy of the test.

The tyrosine test (*12*) is a direct colorometric method for chlorine dioxide. Hypochlorous acid and manganese do not interfere. The test requires rather close control of time, however, and has a limited pH range.

Conclusions

From the results of the questionnaire it may be concluded that chlorine dioxide may serve as a good substitute for chlorine as a disinfectant and, in places where chlorophenolic taste and odor are a problem, it is the chemical of choice. Prechlorination seems to serve well in supplying the chlorine demand, and, even though chlorophenols are formed, subsequent application of chlorine dioxide removes these odor-producing substances. Chlorine dioxide also seems to oxidize iron and manganese well. Process control in the generation and application of chlorine dioxide is not too well done in many instances.

The results of the present experiments indicate that a molar ratio of chlorine to chlorite of 1:2 produces chlorine dioxide with no residual of the reactants. Increasing the ratio results in residual chlorine and this increases the rates of the reactions forming chlorine dioxide. The increase in rate is not as significant as it may appear, however, because the concen-

trations of the reactants in the generator are several times as large as those used in this research. As a result, the rate of the reaction in the generator probably would be much greater than the rates in these experiments. Lowering the pH of the reaction solution decreases somewhat the yield of chlorine dioxide from the chlorite, but it also increases the rate of the reaction. Control of pH can be maintained by controlling the flow of solution water to the chlorinator.

The most precise method of measurement of mixtures of chlorine dioxide and chlorine commonly available in a water plant is the starch–iodide method at pH 1–1.5. Measurement of chlorine dioxide and chlorine or chlorine dioxide only (after chlorine is removed) is possible by the method described by Post and Moore (*10*).

The question of what are the best points to apply chlorine and chlorine dioxide cannot be answered except by analyses at the local water plant. The possibilities are: chlorination with subsequent addition of chlorine dioxide, with or without excess chlorine; or application of chlorine dioxide, with or without excess chlorine.

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Electrophoretic Studies of Water Coagulation

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A paper presented on Apr. 23, 1958, at the Annual Conference, Dallas, Tex., by Janet B. Pilipovich, Research Asst., A. P. Black, Research Prof., Fred A. Eidsness, Assoc. Research Prof., and T. W. Stearns, Prof., Dept. of Chemistry, Univ. of Florida, Gainesville, Fla. This investigation was supported by Research Grant RG-4516 from the National Institutes of Health, USPHS, Washington, D.C.

THE importance of alum coagulation in removing colloidal impurities from water is well known. Although much valuable experimental work has been done on the problems involved and although the techniques for coagulation with alum are well advanced, the mechanisms have never been completely elucidated. Coagulation with alum, as other coagulations, requires that a colloidal suspension be made unstable. The two factors related to the stability of colloidal suspensions are the zeta potential (sometimes incorrectly referred to as the "charge") and hydration. When coagulation of a colloidal suspension occurs, the degree of hydration or the zeta potential, or both, are insufficient to maintain suspension stability. As the isoelectric point is approached, the zeta potential and hydration decrease and coagulation may occur.

Most of the laboratory research that has been done in the past in connection with water clarification has been in coagulation with aluminum or ferric salts. The formation and properties of alum and ferric flocs, and the effects of varying the initial pH with sodium hydroxide or calcium hydroxide in the presence of different concentrations of electrolytes commonly found in water, have been the subject of many investigations (*1–12*). Workers have found that good flocculation with both alum and ferric sulfate occurs within a relatively narrow pH range. Unfortunately, these results have also been considered true for the coagulation of clay suspensions. This has led to the belief that there is but a narrow range of coagulant dosage within which good flocculation will result, and that the coagulant dosage for all waters must be held within these limits.

Various theories have been proposed to explain the role of alum in the coagulation of turbid waters. In 1948, Black (*13*) attempted to summarize existing theory as to the mechanism of coagulation. He first postulated that organic color and turbidity were negatively charged colloidal particles, or, more accurately, colloids with negative zeta potential. According to him, coagulation takes place in three phases:

1. As the coagulant dissolves and the trivalent aluminum or ferric ions become available, they neutralize the negative charge on the particles of color or turbidity, and . . . their neutralizing power is very great. This, in the opinion of

most authorities, is the most important phase of coagulation and it takes place long before the visible formation of floc particles. It is evident that this action will be more efficient if the coagulant can be brought into intimate contact with the material to be removed before secondary reactions can take place. This clearly implies the desirability of rapid mixing as the first step in coagulation.

2. When the positively charged aluminum or ferric ions have neutralized a considerable portion, perhaps most, of the negatively charged colloidal particles of color or turbidity, the resulting particles may be called microflocs for the purpose of this discussion, since they are still beyond the limits of visibility and far too small to settle under the influence of gravity. Furthermore, it has been shown that in the acid range of coagulation most commonly employed they still retain positive charge, possibly due to the adsorption of positively charged hydrogen ions from the solution. We are now dealing, therefore, with a positively charged colloid which has the capacity to neutralize the negatively charged colloid. These positively charged microflocs can therefore continue to remove negatively charged particles of color or turbidity, and this constitutes the second phase of coagulation.

3. During both of the above phases no visible floc particles have formed. The mechanical treatment of the water from this point forward should consist of slow stirring, termed by some authors "conditioning," in order that these tiny microflocs may cluster together and agglomerate with the formation of floc particles which steadily grow in size until they are in a proper condition for sedimentation. During this phase of floc growth, the third action, that of surface adsorption, takes place. . . . It is sufficient only to say that the amount of surface area exposed by the innumerable particles of floc is very great and that impurities in the water may be adsorbed on these active surfaces. It should be emphasized, however, that the formation of a large and well formed floc, while important from the standpoint of sedimentation, is not necessarily the criterion of successful coagulation, since the most important functions of the coagulant take place, as has been shown, before the floc ever attains visible size.

Langelier and Ludwig (*14*), who were among the first to emphasize the chemistry of clay suspensions, proposed the theory that the aluminum ions added first replace all of the exchangeable cations present in the colloidal system. When this has been accomplished, the clay is neutralized—that is, the isoelectric point has been reached. They further state that the neutralization of the zeta potential to the isoelectric point is not sufficient to effect what they term "rapid coagulation" and a small amount of alum must be added. This excess "binder" alum hydrolyzes, and the hydrolysis products serve to bind the flocs together for rapid settling.

Mattson (*15*), after extensive electrophoresis studies, concluded that the products of hydrolysis of the aluminum salt are the most effective in neutralizing the zeta potential of the clay particle; furthermore that, at the pH at which coagulation of turbid waters takes place, the hydrolysis products of the aluminum salt would always play the major role in zeta potential neutralization. Mattson's data indicated further that coagulation takes place well before the isoelectric point is reached. In other studies (*16*), Mattson stated that the amount of methylene blue necessary to reach the isoelectric point is directly proportional and very nearly equal to the base-exchange capacity of the clay. Methylene blue does not dissociate appreciably, however, and it is quantitatively

adsorbed by the clay. This is not necessarily true for aluminum salts or their hydrolysis products.

Although the theories of Black and Langelier do not agree completely, there is agreement to the extent that both investigators consider the aluminum ion as playing the major role in changing the zeta potential. Both theories differ radically from that proposed by Mattson, however.

Electrophoretic Theory

Before the electrophoretic data are presented, some terms will be briefly defined and discussed. More rigorous definitions are given by Abramson (*17*), and Abramson, Moyer, and Gorin (*18*). It cannot be too strongly emphasized that these two books must be carefully studied by anyone contemplating work in the field of electrophoresis. A method of study of microelectrophoresis, suggested by Moyer (*19*), should be consulted also.

The movement of particles in an electric field is called *electrophoresis*; an older name is *cataphoresis*.

A liquid in contact with a surface such as glass may possess a potential with respect to it. If an electric field is applied to such a system there will be a movement of the liquid along the surface as a result of this potential. This phenomenon is called *electroendosmosis*. In a closed system, such as flat, microelectrophoresis cell, liquid that flows along the surfaces returns in the center of the cell. Thus there are two stationary levels in the cell where the flow of liquid is zero, and the velocity of particles may be measured directly without interference from the flow of liquid.

From the laws of laminar streaming of viscous liquids between parallel walls, Smoluchowski's equation gives the levels at which the velocity of liquid is zero if the cell width is great compared to its thickness. This equation is:

$$X = \left(\tfrac{1}{2} \pm \frac{1}{\sqrt{12}}\right) X_1$$

$$= 0.211X_1 \text{ or } 0.789X_1$$

where X_1 is the total depth, and X is the upper stationary level or the lower one.

When the ratio of cell width to cell thickness is not great, Komatagata's equation, which follows, gives the position of the stationary levels in terms of the fractional depth a, measured from the top of the cell, where k is the ratio of width to thickness:

$$a = \tfrac{1}{2} \pm \sqrt{\frac{1}{12} + \frac{32}{\pi^5} k}$$

The difference in potential between the diffuse layer with its ions surrounding a particle and a point at a distance from the particle at which there is an equal number of positive and negative ions, is called the *zeta potential*. In his concept of the double layer, Helmholtz postulated a rigid, single layer of oppositely charged, movable ions neutralizing the fixed surface layer of ions, the two layers being within molecular distance of each other. A more useful concept has been the diffuse, electric, double layer suggested by Gouy. This diffuse layer is formed by the electric forces of the charged particle, which attract ions of opposite sign and repel ions of like sign. A counteracting force, which acts on all the ions, is their tendency to diffuse away from the surface. At equilibrium there results a statistical distribution of ions so that the num-

ber of oppositely charged ions near the particle will be, over a time average, greater than the number of ions of the same sign. Thus an ion atmosphere is built up, extending from the surface of the particle to the bulk of the solution. The thickness of this diffuse double layer—the distance from the surface to the "boundary" of the ion atmosphere that moves with the particle—may reach microscopic dimensions. The movement of a particle in an electric field depends, among other things, upon this zeta potential, rather than the charge of the particle. At the isoelectric point this zeta potential is zero.

When a particle does not migrate toward either electrode in an electric field, it is said to be at its *isoelectric point.*

The velocity of a particle in an electric field, expressed in microns per second per volt per centimeter (μ/sec/v/cm), is the *electrophoretic mobility.* Although the zeta potential may be calculated from the mobility by multiplying by a constant, in most coagulation studies it is convenient to use mobility values directly.

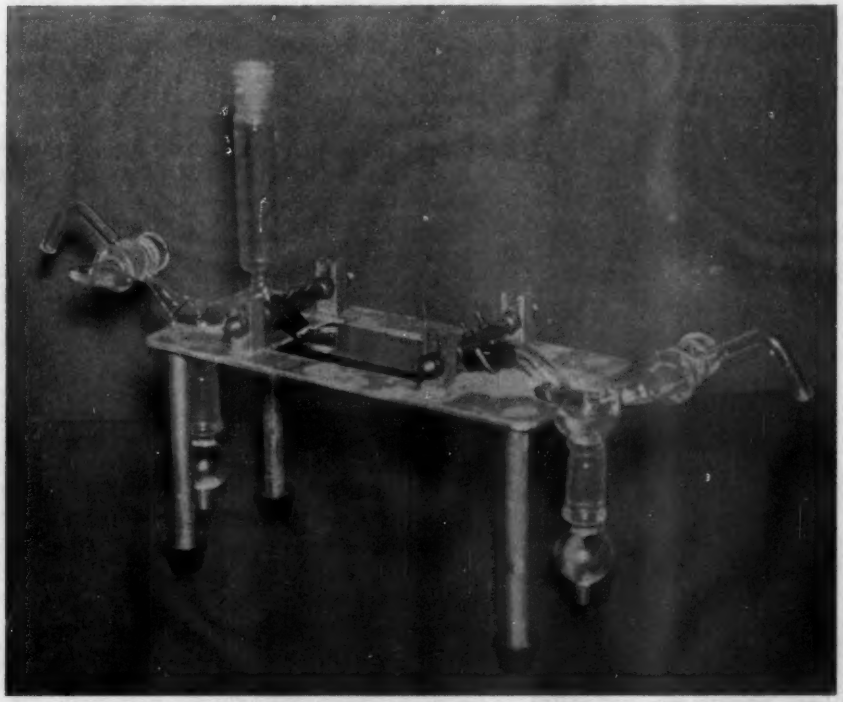

Fig. 1. Briggs Cell With Supporting Frame

The frame is provided for mounting the cell on the stage of a microscope.

Preliminary Experiments

Preliminary experiments using the microelectrophoresis cell * indicated that satisfactory results could not be obtained for one or more of the following reasons.

1. The working distances of available objective lenses (greater than 10×) were not large enough to reach the lower stationary level, which would be desirable in order to check results obtained at the upper stationary level. When the 10× objective and 25× ocular lenses were used, the microscope was not sensitive enough for precise results.

2. Electrolysis occurred with the solutions used when the applied potential was such as to give convenient timing of particles. The gases formed disturbed the electroendosmotic flow of liquid which affected the observed velocity of the particles.

3. No convenient method of checking the cell was at hand to insure that reliable results could be obtained.

4. Great care was needed to insure that observations were made through the optical axis of the cell.

Microelectrophoresis Cell

All of the electrophoretic data presented were obtained using the flat microelectrophoresis cell designed by Briggs (*20*) and shown in Fig. 1. This cell is well adapted for use with solutions of very low ionic strength, such as those encountered in water coagulation investigations. A line drawing of the cell, a description of its construction and use, and a suggested wiring diagram are given by Briggs. The cell was provided with a frame suitable for supporting it on the stage of the microscope with the cell horizontal to the microscope axis.

Optical Equipment

A microscope with 25× ocular lens and a 40× water immersion objective was used. The fine adjustment was calibrated against a standard-thickness glass slide made by cementing a flat, thin, coverslip on a slide with hot balsam. The thickness of the coverslip was determined by measuring the thickness of both the double and single layers of glass with a micrometer caliper, and subtracting to obtain the thickness of the coverslip. The value of the thickness was compared with the value on the fine adjustment by focusing first on the top of the coverslip and then moving the slide and focusing down on it with the fine adjustment. This was done with consecutively higher settings of the fine adjustment to cover its entire range. Since the fine adjustment was found to be essentially linear up to 1,150 divisions, only this portion was used. Each division of the fine adjustment was equal to 1.008 μ.

An ocular micrometer † was inserted in the eyepiece and calibrated against a stage micrometer in the usual manner, using the 40× water immersion objective and the 25× ocular lenses. A microscope lamp focused to give parallel rays of light was placed about a foot from the microscope to avoid heating the cell. The light was passed through about ½ in. of saturated $CuSO_4$ solution to remove heat waves and to give added contrast.

* The Mattson cell with accessories was obtained from the A. H. Thomas Co., Philadelphia, Pa.

† Howard counter; a product of Howard Clock Products, Inc., Waltham, Mass.

The width of the cell was measured by focusing on one edge and then, after the cell was moved to the other edge by the mechanical stage, the difference was read on the vernier of the stage. The average depth of the cell was determined with the 40× water immersion lens, with the cell full of water. cm, 0.09702 cm, and 0.226 sq cm, respectively.

The positions of the stationary levels were obtained by calculation from Komagata's equation. Since the value of k (in that equation) for the cell was 24.02, the stationary levels were at 20.4 per cent of the depth below

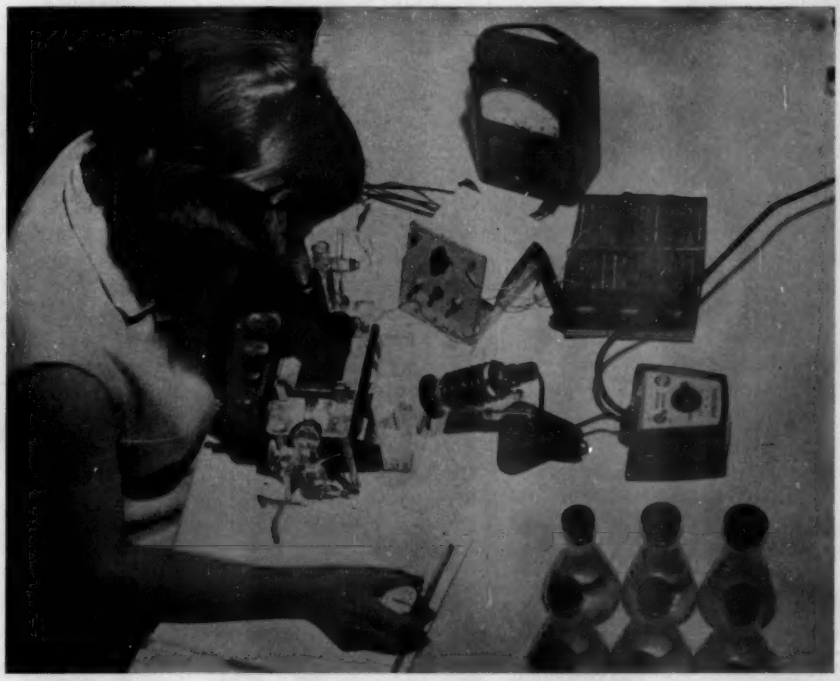

Fig. 2. Briggs Cell With Accessory Equipment

This is all of the equipment as it was set up for a typical run; the Briggs cell is mounted on the microscope.

The cross-section area was obtained by multiplying the inside width at the center by the average depth measured at different points across the width of the cell. The average width, the average depth, and the cross-section area, all near the center of the cell, were 2.33

and above the upper and lower surfaces, respectively. The value for the depth, an average obtained by measuring the depth at several positions close to the center of the cell, was 967.3 divisions on the fine adjustment of the microscope. Thus the stationary levels

were at 197.3 fine-adjustment divisions below the upper and above the lower surfaces, respectively. When measurements were made on suspensions, a parabolic, dark-field condenser was fitted to the microscope.

Electrical Apparatus

Current for the cell was obtained from six 22.5-v. batteries, which provided 135 v, and the voltage was controlled by a potentiometer arrangement with both an on–off switch and a polarizing switch, in order that the electric field could be conveniently reversed in the cell. The current was determined with a milliammeter in the circuit. Wiring diagrams are given by Briggs (*20*) and Abramson, Moyer, and Gordin (*18*). The cell and its accessory equipment are shown in Fig. 2.

Because field strength (volts per centimeter) within the cell was determined by using Ohm's law, the resistance values of the suspensions were needed. These were found with a conductivity bridge.* The standard reference solution used was a 0.5 g/l NaCl solution, which had a conductivity of 1,000 micromhos at 25°C.

The complete setup was checked by measuring the mobilities of human red blood cells in μ/15 phosphate buffer at pH 7.35. The mobility values obtained in two determinations were 1.25 and 1.35 μ/sec/v/cm at 25°C, in agreement, within the limits of error, with the value reported by Abramson.

Procedure

The procedure for making a determination of the mobility of a suspension was as follows: Sufficient mercury was added to each electrode vessel to cover completely the platinum wire which was to be connected later to the potentiometer arrangement. Mercuric nitrate solution (150 g/l) was added to fill each vessel to its constricted portion, then potassium nitrate solution (170 g/l) was added to fill each vessel. Each electrode vessel was firmly seated in the apparatus. Each suspension, at room temperature, was used to wash out the cell, which was then carefully filled with the suspension to avoid bubble formation. A thermometer was placed immediately in front of the microscope and temperatures were recorded at the beginning and end of each determination. The apparatus then was centered on the stage of the microscope and the electrode vessels were connected to the potentiometer arrangement. To carry out these operations, the stopcocks were turned to the appropriate positions, and the light source was turned on. With the fine adjustment appropriately set, the microscope was focused on the bottom of the cell with the coarse adjustment. The fine adjustment was turned the necessary number of divisions to reach the lower stationary level. Then the switch was turned on and the potentiometer was adjusted to give velocities that would allow convenient timing of particles. The milliammeter reading was noted. The current was kept constant during a set of readings by appropriate adjustment of the potentiometer. A stopwatch was used to time particles traveling a given apparent distance on the ocular micrometer. Seven or more particles were timed in each direction, alternating the direction of movement after each observation by using the polarizing switch. Then the upper stationary level was reached by turning the fine

*Model RC-16B1; a product of Industrial Instruments, Inc., Cedar Grove, N.J.

adjustment the appropriate number of divisions, and observations were made as described above. Three or more measurements were made in each direction at the upper level in order to check the readings at the lower level where observations were more conveniently made. The time value used in a mobility calculation was an average of the time values obtained in a series of observations.

The conductance of the suspension was measured on the conductivity bridge and the specific resistance was calculated. Calculation of mobility values required the use of the following equation.

$$M = \frac{dX}{tIR_s}$$

where M is the mobility; d is the distance in microns traveled in t seconds; X is the cross-section area at the center of the cell in square centimeters; I is the current in amperes and R_s is the specific resistance of the suspension in ohms per milliliter. The mobility values obtained by using the equation above were calculated to 25°C by using a coefficient of 0.02 per degree Centigrade to take care of changes in viscosity, because mobility is directly proportional to viscosity, and the viscosity of water and dilute aqueous solutions increases about 2 per cent per degree for temperatures around 20°C.

The zeta potential may be calculated from the equation,

$$\zeta = \frac{4\pi\eta v}{HD}$$

where ζ is the zeta potential, η is the viscosity, v is the velocity in centimeters per second, H is the potential gradient in volts per centimeter, and D is the dielectric constant. The zeta potential may be estimated from mobility values reported later, by multiplying mobility values by

$$\zeta = \frac{4\pi\eta}{D} \cdot 10^{-4}$$

During the operation of the cell, if observations in one direction did not agree with those in the other, or if observations at one stationary level did not agree with those at the other level, the cell was taken apart and cleaned thoroughly with dichromate cleaning solution. When movement of particles was observed without application of the current, the stopcocks and the electrode vessels were reseated.

Clay Suspension Studies

An investigation was made of:

1. The effect of the base-exchange capacity of the clay on the amount of alum necessary for reaching good coagulation, or the isoelectric point, or both
2. The type of curve obtained with clays of various base-exchange capacities by plotting alum dosage against final turbidity.
3. The effectiveness of alum in neutralizing the zeta potential at initial pH values of the clay suspension of from 3.3 to 10.5 in an effort to determine whether the trivalent aluminum ions or the hydrolysis products are more effective in neutralizing the zeta potential
4. The relationship between the amount of alum necessary for good coagulation and the amount of alum necessary to reach the isoelectric point
5. The correctness of the hypothesis that a certain amount of binder alum is necessary for rapid coagulation. In determining the latter, the work of

Langelier, who used nonhydrolyzing $CaCl_2$, was repeated and extended by finding the mobilities of the clay particles before and after the addition of alum.

Effects of Base-Exchange Capacity

The clays that were used in the investigation were obtained from Ward's Institute of Natural Science and originally mined and characterized by the American Petroleum Institute. Eight clays were ordered for consideration, but only four suspended well enough for use. These were Illite 35, Montmorillonite 20, Montmorillonite 23, and Kaolinite 4. Of these four, Montmorillonite 23 was not adaptable to electrophoretic measurements because of its extremely small particle size before coagulation and the large dense floc that was formed when it was coagulated. Therefore, although jar tests were run on Montmorillonite 23, mobilities were not determined. The clay used in research by the Robert A. Taft Sanitary Engineering Research Center, Cincinnati, was also used in these studies and is referred to as Taft Center clay.

TABLE 1

Base-Exchange Capacity Determined by the NH_4Ac and $BaCl_2$ Methods

Clay	Base-Exchange Capacity (E_B) $\mu e/100$ g*	
	NH_4Ac Method	$BaCl_2$ Method
Montmorillonite 20	66.3	82.3
Montmorillonite 23	85.2	96.2
Illite 35	—	11.0
Kaolinite 4	10.2	10.2
Taft Center	5.9	9.2

* Milliequivalents per 100 g.

The ammonium acetate method for determining the base-exchange capacity (E_B) of the clays under consideration was first used, but later abandoned because of inability to obtain reproducible results and the physical difficulties encountered in this method with Illite 35. Therefore, the barium chloride method proposed by the US Regional Salinity Laboratory (*21*) produced reproducible results. Table 1 gives the base-exchange capacity of the several clays as determined by the ammonium acetate and barium chloride methods.

From the base-exchange capacity in milliequivalents per 100 grams, determined by the barium chloride method, and the weight obtained by evaporation of 100 ml of each suspension used, the base-exchange capacity in microequivalents per liter ($\mu e/l$) was calculated.

In the first part of the work, jar tests were used. This procedure included a 20-min stirring period at 40 rpm and a 30-min settling period, after which samples were withdrawn using the Cohen (*22*) technique and percentage transmittance was read on a photelometer * employing a 150-mm light path, which had been calibrated against a Jackson candle turbidimeter. For mobility, pH, and conductance measurements, samples of approximately 200 ml were poured into Erlenmeyer flasks immediately after stirring was discontinued. Although the jar test is undoubtedly the best method of obtaining indications of the minimum dosage for good flocculation, it failed to give reproducible data for pH, conductance, and mobility, probably owing to the low buffer capacity of the sus-

* Lumetron; a product of Photovolt Corp., New York, N.Y.

pensions. Another method, hereafter called the alum titration method, was devised and gave reproducible results. In this method the clay suspension was made up in 4-liter polyethylene bottles, and 200-ml samples of the suspension were accurately measured and transferred to 250-ml Erlenmeyer flasks, which were stoppered immediately. The proper alum dosage was made until 12 hr after completion of the test. Each series of alum dosages on a particular clay was run on a prepared stock suspension. Results from a particular dosage of alum on a particular clay could not be reproduced exactly for different stock solutions. When plotted, however, the results produced the same type of curve, which sometimes coincided. The

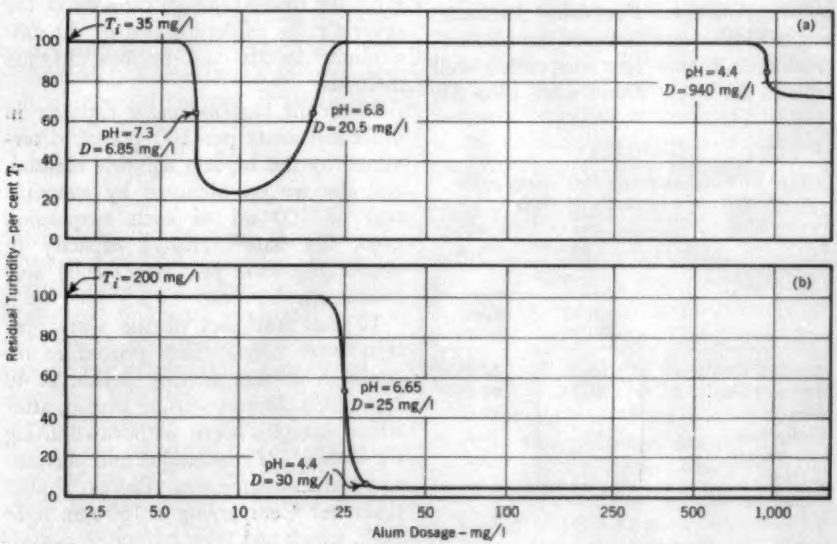

Fig. 3. Effect of Variable Exchange Capacity on Turbidity

Fig. 3a: initial turbidity T_i *is 35 mg/l;* E_B *is 20 μe/l. Fig. 3b:* T_i *is 200 mg/l;* E_B *is 250 μe/l.*

added to each sample with a microburet. The samples were shaken during the addition of alum and then allowed to stand for 12 hr. In this method final turbidity was not determined, although floc formation was noted.

For both the jar test and the alum titration methods, the measurements, except for final turbidity, were not

curves plotted in this work represent typical data obtained from at least four series run on each clay.

In the work conducted by Langelier and Ludwig (*14*), where residual turbidity was plotted against alum dosage, two general types of curves were obtained. In clays of low base-exchange capacity (20 μe/l), shown in Fig. 3a, coagulation occurred in a rather nar-

TABLE 2

Alum Dosages Needed for Good Coagulation and to Reach the Isoelectric Point

Clay	Alum Dosage—mg/l	
	For Good Coagulation	For Isoelectric Point
Kaolinite 4	3	26
Illite 35	3	28
Montmorillonite 20	23	140
Taft Center	6	33

row zone between dosages of 6.8 and 20.5 mg/l alum. This curve also indicates that at a dosage of 940 mg/l, less coagulation occurred. Clay having a high base-exchange capacity of 250 μe/l, as indicated by the curve in Fig. 3b, first coagulates at a dosage of 30

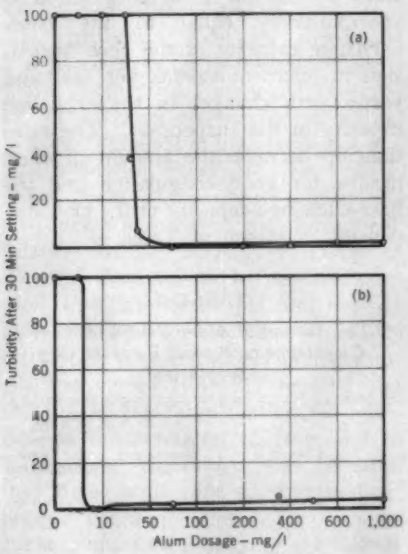

Fig. 4. Coagulation of Sodium-Saturated Clays With Alum

Fig. 4a: Montmorillonite 20 clay; 50 mg/l NaCl; E_B *is 3,417.5 μe/l. Fig. 4b: Taft Center clay; 50 mg/l NaCl;* E_B *is 10.5 μe/l.*

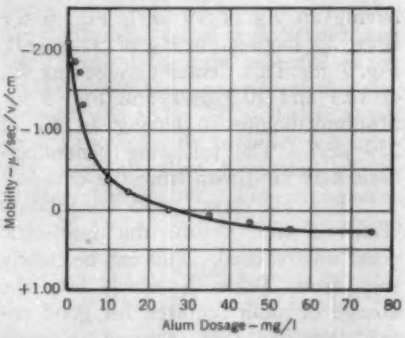

Fig. 5. Effects of Alum Dosage on Mobility—Kaolinite 4

Clay concentration is 186 mg/l; E_B *is 19 μe/l.*

mg/l of alum and at increasing dosages up to 1,500 mg/l. A series of similar jar tests was conducted on all of the clays that were used in this work. To all of these clay suspensions, 100 mg/l $NaHCO_3$ was added, because Langelier had used this form of alkalinity in most of his experiments. With each clay, regardless of the base-exchange capacity of the suspension, which ranged from 10 to 300 μe/l, a curve was obtained as typified by Fig. 3b. The alum dosages used ranged from 0 to 2,500 mg/l in all tests. Typical curves for Taft Center and Montmorillonite 20 clays are shown in Fig 4.

Effect of Alum Dosage on Mobility

A few experiments were mainly concerned with the effect of alum dosage on mobility. The clays used for these experiments were prepared by the sodium saturation method. In these tests, 30 mg/l NaCl was added to each suspension to obtain more reproducible conductivity measurements.

Figure 5 indicates the effect of alum dosage on mobility for Kaolinite 4

having an E_B of 19 μe/l, Fig. 6 for Illite 35 having an E_B of 31.4 μe/l, Fig. 7 for Taft Center clay having E_B of 11.1 and 10.5 μe/l, and Fig. 8 for Montmorillonite 20 having an E_B of 239 μe/l. The following generalizations may be drawn from the data:

1. For all clays, good coagulation occurred well before the isoelectric point was reached. This can be clearly seen from Table 2, which lists the dosage of alum required for good coagulation and that required to reach the isoelectric point.

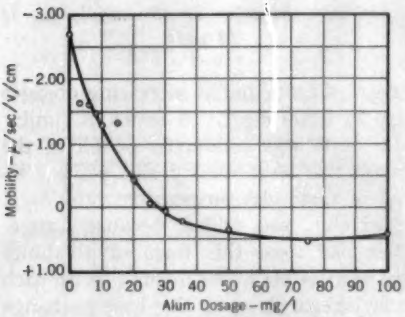

Fig. 6. Effects of Alum Dosage on Mobility—Illite 35

Clay concentration is 286 mg/l; E_B *is 31.4 μe/l.*

2. After the isoelectric point was reached, the zeta potential became positive and remained reasonably constant over the range of alum dosage employed. In no case did the floc attain a higher migration velocity than + 0.82 μ/sec/v/cm.

3. The curves shown in Fig. 5–7 are very similar in that the isoelectric points were essentially the same in each case. From Table 1 it can be seen that these three clays have essentially the same base-exchange capacity in milliequivalents per 100 g. The concentration of the clay, therefore, did not seem to affect the amount of alum needed to reach the isoelectric point for these three low base-exchange capacity clays. Table 3 gives data for Taft Center clay to illustrate this point.

TABLE 3

Alum Dosage at the Isoelectric Point and the E_B *for Taft Center Clay*

Alum at the Isoelectric Point mg/l	E_B μe/l
38	119.0
33	11.1
36	44.0
33	10.5

4. For high base-exchange capacity clays (the Montmorillonites) the number of microequivalents per liter of alum needed for good coagulation is approximately equal to the base-exchange capacity of the clay suspension in microequivalents per liter and varies with changes in the exchange capacity of the suspension. The relationship between the amount of alum needed for good coagulation and the base-exchange capacity of the clay suspension is shown in Table 4.

TABLE 4

The Amount of Alum Needed for Good Coagulation at Various E_B *of the Clay Suspension*

Clay	E_B of Clay Suspension μe/l	Alum Needed for Good Coagulation μe/l
Illite 35	11.5	27
Illite 35	31.0	27
Kaolinite 4	10.2	27
Taft Center	44.0	54
Taft Center	10.5	54
Montmorillonite 20	282.0	288
Montmorillonite 20	271.0	207
Montmorillonite 20	83.0	72
Montmorillonite 23	340.0	387

5. From the curves in Fig. 5–7, it appears that once coagulation occurs, the absolute value of the mobility never exceeds that attained when coagulation first occurred. If one accepts the concept of a critical zeta potential, there is no reason to expect that there is any region where coagulation will not occur if the alum dosage is increased beyond the minimum that is required for coagulation.

Effect of pH on Zeta Potential

The next experiments were designed to determine the effect of pH on the efficiency of alum in changing the zeta potentials on clay particles. Taft Center clay was used for all of these experiments because of its very poor settling qualities, which made it easier to determine the mobilities of the coagulated material. The clay suspension was made up in the 4-liter polyethylene bottle in the usual manner. Samples of 200 ml were transferred to 400-ml beakers. The pH of the suspension was adjusted with either HCl or NaOH, added from a microburet, while the suspension was stirred with a magnetic mixer. During stirring, a dosage of 35 mg/l alum was added to each sample. Both the initial pH and the pH after the addition of alum were determined. The initial pH of the sample was varied from 3.3 to 10.5 and the pH of the sample after the addition of the alum varied from 3.3 to 10.3. The experiment was repeated four times with very good reproducibility. Figure 9 shows the type of curve obtained by plotting the pH of the sample after the addition of 35 mg/l of alum against the mobility. This curve shows the effect of changing the pH and includes the effect of small changes in ionic strength that occurred because of the additions of NaOH and HCl. The data show that the alum dosage had very little reducing effect on the zeta potential of the colloid when the final pH of the suspension was above 7.0, and that at pH values above 8.0 the mobility was actually more negative than that of the original suspension. The explanation may be that at pH 7.0 the aluminum sulfate is largely hydrolyzed and a nearly neutral $Al(OH)_3$ floc is produced. Above that value, the increase in negative zeta potential is probably caused by the adsorption of hydroxide ions.

TABLE 5

Effect of pH on Suspension Mobility

pH Before Addition of 35 mg/l Alum	pH After Addition of 35 mg/l Alum	Mobility μ/sec/v/cm
3.31	3.31	−0.53
3.97	3.93	−0.22
4.51	4.15	−0.13
4.93	4.25	0.00
5.37	4.28	0.00
5.63	4.30	+0.03
6.11	4.35	+0.07
6.31	4.41	+0.10
6.72	4.43	+0.11
7.00	4.42	+0.16
7.67	4.43	+0.16
8.13	4.45	+0.16
9.00	4.51	+0.16
9.48	4.51	+0.19
10.00	5.34	−0.19
10.10	5.84	−0.28
10.15	6.58	−1.50
10.23	7.00	−1.51
10.29	7.55	−1.78
10.34	8.17	−2.35
10.40	9.22	−2.96

Figure 8 also shows that when the final pH of the suspension to which alum was added was 3.3, the zeta potential of the clay colloid remained negative. Increasing the pH of the suspension decreased the negative zeta

potential of the colloid until at a final pH of approximately 4.3 the zeta potential became and remained positive until a final pH of approximately 5.3 was reached. When the pH after addition of 35 mg/l of alum was plotted against mobility, the most efficient pH for zeta potential reversal appeared to be about 4.5. A pH titration curve was made using 0.1000*N* aluminum sulfate and titrating with 0.1251*N* NaOH. The results show a maximum buffer capacity between pH 3.75 and pH 4.25, centering around a pH of 4.0. Theriault and Clark (*1*), in the first of a series of six classical papers produced by USPHS chemists in 1923–25, produced a similar curve, and Miller (*2*), in another paper of the same series, showed that, up to the addition of 2.5 moles NaOH per mole of aluminum, the precipitate remains nearly constant in composition and approximates the formula $5Al_2O_3 \cdot 3SO_3$.

Table 5 shows, in a different way, the region of greatest buffer capacity of the system. When the constant alum dosage of 35 mg/l was added to clay suspensions having initial pH values of 4.9–9.5, the alum added controlled the final pH. Through this range of initial pH values the final pH varied only from 4.25 to 4.51. Above the latter value the buffer capacity of the system is broken and the final pH increases rapidly with increase in initial pH. Table 5 also shows that the mobility remains very nearly constant throughout the pH range of 4.25–4.51. It must be emphasized that this work was done on only Taft Center clay and still needs to be done on the rest of the clays.

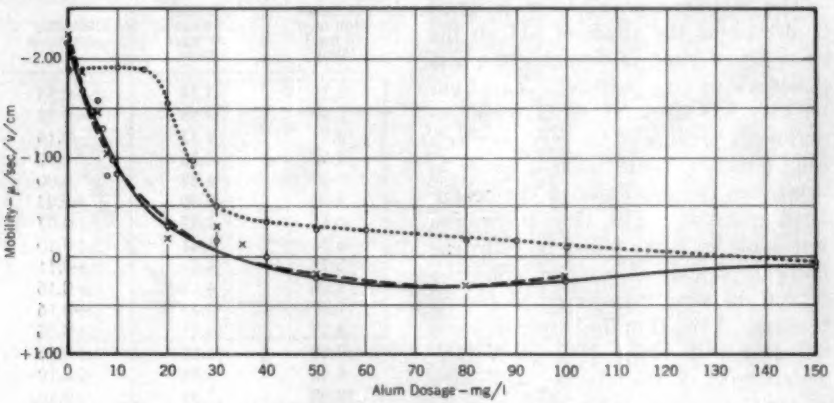

Fig. 7. Effects of Alum Dosage on Mobility

The solid and dashed curves represent two runs with Taft Center clay. The dotted curve represents a run with Montmorillonite 20. Concentrations are: solid curve, 115 mg/l; dashed curve, 122 mg/l; dotted curve, 290 mg/l. E_B *are, respectively, 10.5, 11.1, and 239 μe/l.*

'Binder' Alum Hypothesis

The fifth and last item to be studied was Langelier's hypothesis (*14*) that a certain amount of "binder" alum is

TABLE 6

Effect of a Nonhydrolyzing Salt and Alum on Mobility for Illite 35

$CaCl_2$ Dosage me/l	Alum Dosage mg/l	Mobility μ/sec/v/cm
0.0	0	−2.08
0.5	0	−1.53
0.5	1	−1.42
0.5	3	−1.32
0.5	6	−0.87

necessary for rapid coagulation. His work with $CaCl_2$ was repeated and extended by determining the mobilities of the clay particles after the addition of alum. The experiments with $CaCl_2$ showed that the minimum dosage necessary to coagulate a suspension having a base-exchange capacity of greater than 250 μe/l would not coagulate a clay suspension (Illite 35) having a base-exchange capacity of approximately 10 μe/l. Mobility determinations revealed, however, that this amount of $CaCl_2$ did not reduce the zeta potential on the clay to zero and addition of alum served to coagulate the clay and reduce the zeta potential (Table 6).

Conclusions

1. As the dosage of alum increases, the zeta potential on the clay particles decreases sharply until shortly before the isoelectric point is reached. This potential then decreases very slightly with increasing dosages, and very shortly after passing the isoelectric point it levels off.

2. Coagulation occurs well before the clay suspension reaches the isoelectric point. All the clays studied were coagulated by any dosage of alum from that amount required for first coagulation to the maximum dosage of 2,500 mg/l.

3. For the low base-exchange clays no relationship seems to exist between the concentration of clay suspension and the concentration of alum needed for first floc formation, whereas for high base-exchange clays there does appear to be such a relationship.

4. Low base-exchange clays require considerably less alum for flocculation than high base-exchange clays.

5. No quantitative relationship appears to exist between the base-exchange capacity of the suspension and the isoelectric point. The dosage of alum required to reach the isoelectric point is higher for high base-exchange capacity clays than for low base-exchange capacity clays, but no direct or constant relationship exists. In all cases the quantity of alum in microequivalents per liter needed to reach the isoelectric point is many times the base-exchange capacity, expressed in microequivalents per liter.

6. Although it is realized that the data obtained with such a small number of clays are insufficient to draw any general conclusions, the results from the systems used seem to indicate

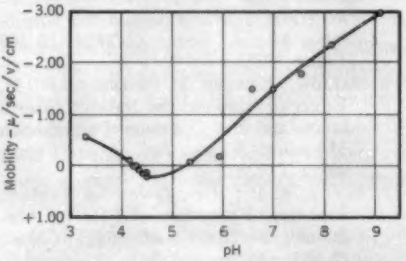

Fig. 8. Effect of pH on Mobility—Taft Center Clay

The curve represents a run made to test the effect of pH on mobility, the following being kept constant: alum dosage, 35 mg/l; clay concentration, 145 mg/l; E_B, *13.3 μe/l.*

that the hydrolysis products of aluminum sulfate are a stronger coagulating agent than the tripositive aluminum ion.

7. Electrophoresis is a potentially valuable tool for gaining a better understanding of the complex mechanisms of coagulation.

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Air Pollution and Its Control

EJC Policy Statement

A policy statement prepared by the Air Pollution Committee of the Engineers Joint Council. Members of the committee were: C. A. Bishop (Chairman), AIChE; S. G. Hess, ASCE; R. M. Mahoney, AIME; F. S. Mallette, G. V. Williamson, and L. A. Winkelman, ASME; R. J. Faust, AWWA; G. T. Minasian, AIEE; E. J. Kilcawley, ASEE; P. J. Marschall, ASHAE; F. D. Vermilya, SAME; and E. P. Lange and L. K. Wheelock, EJC. The statement has been officially approved by the AWWA Board of Directors.

THE engineering profession, through its Engineers Joint Council, has developed the following policy principles for consideration by those concerned with air pollution and its control.

Principles

1. The common goal is to maintain a reasonable degree of purity of our air, consistent with

a. The public health and welfare and public enjoyment thereof

b. The continued industrial development of our country

c. The protection of plant and animal life

d. The protection of physical property and other resources.

2. Air pollution means the presence in the outdoor atmosphere of one or more contaminants, such as dust, fumes, gas, mist, odor, smoke, or vapor, in quantities, of characteristics, and of duration such as to be injurious to human, plant, or animal life or to property, or which unreasonably interfere with the comfortable enjoyment of life and property.

3. In the development of criteria for the control of air pollution, it must be recognized that, although the atmosphere is a medium suitable for the disposal of waste products, true conservation requires that the public interest be protected against excessive and unsafe use of the atmosphere for this purpose.

4. Effective criteria are required to serve two purposes, namely, enforcement and protection of the public interest. The first of these can be most effectively accomplished at the points of emission, the second at the points of use. Sound criteria must give relative evaluation of these two measures.

5. In the development of standards, plans, rules, or regulations, due consideration must be given to local conditions, such as topography, meteorology, industrial development, and area planning.

6. Emphasis should be placed upon education and voluntary cooperation by all persons and organizations who may contribute to air pollution or who are interested in its control. Encouragement should be given to groups or associations of municipalities, industries, or other groups who, severally or

jointly, can be of help in planning its effective abatement.

7. Laws with appropriate penalties may be necessary, but their use should be reserved for cases where cooperation and voluntary action do not prevail.

8. During an emergency, such as may develop under adverse meteorological conditions, short-time curtailment of community and industrial activities which contribute to pollution may be necessary. Although such an emergency condition is seldom encountered, it is essential that duly constituted governmental authority anticipate such a problem and be prepared to act through a prearranged procedure.

9. The objective of air pollution control legislation is to recognize the right to the use of the air and the responsibility to avoid its abuse. It is the duty of the engineer to contribute the knowledge of his profession in the preparation of legislation that will accomplish this objective.

10. Air pollution and its control involve many scientific problems that have not yet been solved. There is no simple or quick answer. Continued research in this field is vitally necessary. The engineering profession has the obligation of reaching the best engineering solutions to these problems.

11. It is the responsibility of the engineering profession to participate vigorously in the field of air pollution control.

General Considerations

Although vast in quantity, the air surrounding the earth is, in the present development of scientific knowledge, a limited resource. It consists essentially of oxygen and nitrogen in rather definite proportion, but also contains water vapor and rare gases in varying amounts. Its oxygen is essential to life, and its nitrogen, through the action of plants, provides food. Its temperature and circulation keep us comfortable, and its transparency makes possible the enjoyment of natural beauty, as well as safe aerial, land, and marine transportation. It serves as a filtering and diffusing medium for sunlight and other forms of radiation, reducing them to levels acceptable to plant and animal life, and it is the medium by which water is returned to the land in the form of precipitation.

The air around us, the atmosphere, is continuously exposed to both natural and artificial contamination. Every individual contributes to natural contamination by his metabolism and to artificial contamination by his activities. The activities of industry also discharge large quantities of polluting materials into the atmosphere daily. Fortunately, under most conditions, these pollutants are rapidly dispersed and diluted so that the effect is unnoticeable. It must, however, be recognized that meteorological conditions may and sometimes do exist which prevent the rapid dispersion and dilution of the polluting materials. Such conditions may result in serious air pollution and may create a public nuisance, an economic barrier to further industrial expansion, and a serious health hazard.

The unprecedented expansion of industries and increase in population have caused this problem to develop before basic research essential to an adequate understanding of the many factors involved was possible. Much remains unknown relative to the direct

effect of the type and concentration of contaminants or the actual mechanism by which harmful results are produced in the human body. In certain types and concentrations of pollution, relatively short times of exposure have proven fatal. The effects of long times of exposure to other types and concentrations are not as yet known. There is urgent need for basic research to develop more adequate knowledge in this area.

As the air is a limited resource, its maximum use in the most efficient and economical manner is vitally important. To ignore the air's capacity to stabilize waste products or to overtax this capacity constitutes waste of a primary element in our economy, health, and welfare. The atmosphere is a natural resource that must be shared by all. Control of its pollution is a community problem. The individual must be subject to reasonable limitations on its use as may be required in the public interest.

The sources of natural pollution are many. As a result of natural phenomena, the atmosphere contains gases from the decomposition of animal and vegetable matter; products of volcanic and weathering action and of meteoric disintegration; spores; pollens and bacteria; and, in some sections, other vapors, gases, and particulates. Generally these pollutants are absorbed or stabilized by the atmosphere.

Current technical data support the idea that the contaminants which cause serious pollution are those that result from man's own activity. The atmosphere is used as a disposal medium for man-made waste products. These wastes may be the products either of combustion or of other processes. When mixed together and subjected to sunlight and other natural phenomena, these products cause complicated reactions, producing a multiplicity of secondary effects. The increase in industrial activity and in the concentration of our population has resulted in an increase in both the quantity and the concentration of such waste products in the atmosphere, a condition which often results in serious air pollution in urban areas.

In rural areas, on the other hand, pollution may result from excessive quantities of dust and vapors, both toxic and nontoxic, odors, and pollen. Considerable progress has been made in the development of methods for controlling the sources of such pollution through scientific soil management and other methods of control.

While air movements disperse and dilute contaminating materials, meteorological conditions can be such that these materials may be transported with relatively little dispersion or dilution even over very great distances. Pollens, dusts, and other contaminants from forest fires, wind action, volcanoes, and nuclear tests have been found in the atmosphere far from their sources. A change in meteorological conditions will cause the contaminants to settle out directly or fall to the earth with the rain or snow. As a consequence, air pollution is a world-wide problem.

To prevent detrimental concentrations of atmospheric pollutants, one must recognize what constitutes an offensive discharge and determine the allowable concentration of these constituents. Methods must then be found to keep the character and the amount of discharge under control.

Most often the pollutant causing aggravation evolves from an operation in which some branch of the engineering profession is concerned. Effective and adequate control must, therefore, be started at the source of the pollution by engineering personnel.

Legislation at various levels of government may be desirable. Effective control can result only under legislation which is both fair and equitable, and, at the same time, provides for adequate penalties for violations. It must be carefully prepared and be flexible, yet specific, in order to be adjustable to the needs of all areas.

Responsible administration should start at the lowest government level capable of dealing with this technical problem. The public must be fully informed and accept the fact that each individual is both a contributor and a victim.

Causes of Pollution

Contaminating substances, both gaseous and particulate, are always present in the atmosphere. The quantity, concentrations and characteristics of the contaminating substances found in the air at a particular time and place determine the degree of air pollution.

Air pollution from natural causes is usually of minor concern. However, volcanic gases and ashes have, on occasion, laid waste whole countrysides, and spores and pollen regularly cause distress to large numbers of susceptible people, and fogs interfere greatly with our comings and goings. These are the results of natural phenomena, and at present it is difficult to mitigate these forms of air pollution. It is, therefore, the pollution resulting from man's own activities upon which the efforts of engineers presently can be most fruitfully exerted. Some idea of the complexity of the problem to be solved may be indicated by a brief listing of the major activities of people in our existing society and their contribution to the air pollution problem:

1. Agricultural activities—dusts from land cultivation, fertilization, and crop handling; odors, of both vegetable and animal origin; pollens and insecticides
2. Commercial activities—products of combustion from fuels used for heating and cooking and from garbage and refuse disposal by open burning or incineration
3. Construction activities—chiefly dust
4. Domestic activities—discharges similar to those from commercial activities, differing only because of size and number
5. Industrial and manufacturing operations—products of combustion of fuels, also dusts, gases, and odors arising from materials being processed
6. Transportation—products of combustion from land, marine, and air vehicles, road dust, and tire dust
7. Waste disposal—products of combustion from the burning of waste materials, either in the open or by incineration, and dusts, gases, and odors from the handling of waste materials or from areas where they have been dumped.

Any of these activities can, and on occasion do, cause annoyance to people. Such annoyances can range from the effect of an improperly adjusted domestic heating furnace, which discharges soot that soils the immediate neighborhood, to an open-burning dump spreading a pall of smoke, noxious gases, and odors over a considerable area. They also include many types of commercial and industrial

gases, dusts, or odors which, depending upon their quantity and characteristics, may be annoying or damaging to property.

There is another type of air pollution, which has come into prominence lately. It is a general pollution of the atmosphere above urban and metropolitan areas, which cannot be charged to a single individual or enterprise, but is a result of our complex society. The exhaust from a single automobile in proper mechanical condition is hardly observable. Yet the exhaust from two solid lines of such cars passing through a tunnel becomes so lethal that an elaborate ventilating system is required. Conditions in a narrow street, lined with tall buildings, are scarcely better unless our natural ventilating system, the wind, dissipates the fumes.

Thus, above many of our major metropolitan areas, because of the congestion of population, density of traffic, and magnitude of industrial operations, an immense and ever increasing amount of contaminants is poured forth daily into the atmosphere. There they react, not only with each other, but also with the water vapor and ozone naturally present. The net result is commonly referred to as smog.

The seriousness of the condition depends on two major factors. One is a function of the total amount and characteristic composition of material being discharged into the atmosphere. The other is a function of the meteorology and topography of the region.

The effect of meteorology is pronounced. On one day the air may be clear and visibility unlimited, on the next we can scarcely see the length of a city block. Sustained winds, atmospheric turbulence, and the lack of temperature inversions all help to dissipate the man-made fog above our cities. On the other hand, windless days, a "heavy" atmosphere, and nightly temperature inversions all tend to concentrate, rather than disperse, the pollutants. If these unfavorable atmospheric conditions persist for several days, the concentration of pollutants continues to rise.

Unfavorable topography likewise induces an increase in concentration levels, by confining the polluted atmosphere and preventing its lateral movement. Valleys, or even a range of hills, are the usual unfavorable topographical features.

Methods of Control

Control of industrial and domestic pollution may be attempted in one or some combination of three ways: [1] by dilution, [2] by abolition, or [3] by treatment.

Control by dilution is an age-old method. It has been used, knowingly or unknowingly, from the beginning of time and it will continue to be used as a means of final disposal for wastes. The method has many advantages and much capacity for disposing of contaminants effectively. It fails miserably, however, when its limitations are not strictly respected. These limitations, of course, are as capricious as the winds themselves. Complete reliance on the dilution method may, under adverse weather conditions, result in nuisance or more serious conditions. By taking advantage of favorable factors, such as isolation from urban population and releases of contaminants at reasonably high elevations, however, disposal by dilution can be satisfactory.

Another method of air pollution control is abolition of the sources of trou-

ble. No doubt this is the perfect solution, but, unfortunately, its application is often restricted because of cost or impracticability. Where abolition is practical it should be used in preference to other methods. For example, open fires, with their poor combustion possibilities and attendant hazards, should not be tolerated in most instances.

The third method of air pollution control is by treatment of the wastes to reduce their potency and other unfavorable characteristics before they are discharged into the atmosphere. This approach, in its simplest terms, is an adjunct to the dilution method; it can make the dilution method work to advantage. Many corrective methods are now available to the engineer to treat potential air pollutants. Some of the more common ones are: [1] superior combustion chambers, [2] scrubbing facilities, [3] settling chambers, [4] filters, [5] mechanical separators, [6] electrostatic precipitators, and [7] counteractants. Where applicable, each of these devices has provided a significant contribution to air pollution reduction.

Abatement of air pollution may also be accomplished by centralization of disposal functions as opposed to individual disposal. An example of this method of abatement is the collection of rubbish by a central agency from homes, apartments, and commercial places for complete and adequate disposal by incineration or by a sanitary landfill method. The elimination of innumerable and inefficient individually owned incinerators by this plan, materially reduces the air pollution potential.

Many other practices and programs that were designed with other objectives in mind have helped reduce air pollution. For example, the paving or surfacing of streets and parking lots prevents the development of dust pollutions from these areas on windy days.

Thus, in most circumstances air pollution is amenable to control. Some pollution problems, however, have resisted solution and need the application of research if progress is to continue. In seeking an approach to air polllution control, it is not enough to identify substances from the polluted air and then seek methods of reducing the quantities of these materials. Some of them may be only the innocuous end products of reactions of unstable substances that may be the real cause of the trouble. A knowledge of the chemical components of pollutants while airborne, of the catalytic substances present, of the reactions which occur, and of the shifting equilibria which are reached under varying conditions will be necessary in identifying offensive materials and in developing methods for counteracting them. To meet this and many other challenges in this field, research is required. The recovery of sulfur from stack gases and the design and development of a satisfactory home and apartment incinerator which will minimize air pollution are typical of the problems which need solution through study.

Indiscriminate discharge into the atmosphere of waste materials which may become obnoxious or toxic, simply because no other method of disposal is known, should no longer be condoned. Scientific study and research for the satisfactory control of such discharges should precede the event rather than follow it.

The cost of air pollution abatement should be commensurate with the benefits accruing to the people. Fortu-

nately this condition normally prevails, and, because it does, air pollution control is not beyond our reach. The present thinking on pollution control leans heavily on provisions for the reduction and treatment of wastes prior to the beginning of operations at new plants. By this means, pollution can be controlled before it has a chance to do any damage.

Engineer's Function

Engineering involves directing the forces of nature and the activities of man to his own use, convenience, and welfare. In view of air pollution's causes and effects and the technical nature of its control, the engineering profession is qualified and is duty bound to contribute substantially to the control of air pollution.

Engineers are involved, through research, development, design, construction, installation, operation, and maintenance, in activities that bring into being man-made sources of air pollution. Engineers have already made substantial contributions to the solution of air pollution problems by application of technical knowledge. Many of these contributions have resulted from efforts to utilize fuels and raw materials more effectively, while others have come from efforts specifically directed to minimizing air pollution nuisances and hazards.

Other professional disciplines are contributing to effective air pollution control in many fields, including agriculture, biology, government service, law, medicine, meteorology, politics, public health, science, and soil conservation.

The engineering profession is prepared to discharge its responsibilities in the physical control of air pollution, by full participation with other professional disciplines in establishing and effecting sound policies of control.

Decontamination of Radioactive Sea Water

Minoru Honma and Allen E. Greendale

A contribution to the Journal by Minoru Honma, Radiochemist, and Allen E. Greendale, Radiochemist, both of the US Naval Radiological Defense Laboratory, San Francisco, Calif.

MANY different adsorbents and techniques have been applied in the removal of radioactivity from fresh and waste waters. Alum coagulates (*1, 2*), clay slurries (*3–5*), powdered metal (*6*), ion-exchange resins (*7, 8*), and other chemicals (*9, 10*), have been used with varying degrees of success. Seal and Pecsok (*11*) used the electrodialytic method for radioactivity removal. Lauderdale and Eliassen (*12*) evaluated the radioactive decontamination of municipal water supplies through standard water treatment practices following the nuclear-weapons tests in Nevada in 1955.

Little work has been done in the removal of radioactivity from solutions of high ionic strength. In the radiochemical analysis of sea water, however, Miyake (*13, 14*) showed that 56–96 per cent of the radioactivity could be removed by using activated charcoal, alumina, and silica, or iron and barium salts. A preliminary laboratory investigation of the removal of radioactivity from a static sea water system has shown that approximately 30 per cent decontamination may be obtained by a flocculation technique (*15*). Sea water is a highly saline solution which is approximately 3.8 per cent salt (*16*) and contains a multitude of marine organisms. The complex nature of sea water makes the problem of its decontamination with ordinary municipal water treatment equipment more difficult, especially if a high level of decontamination is expected at nominal costs.

Because coagulation operates through many mechanisms (adsorption, coprecipitation, precipitation, entrainment, occlusion, and isomorphous-replacement ion exchange), the applicability of a coagulation technique to decontamination was investigated. A coagulant that could combine several of these mechanisms in a highly ionic medium would be desirable. The present study was undertaken to evaluate the decontamination efficiencies in sea water of various materials, particularly the silicates, for a single-stage coagulation and sedimentation method.

The study consisted of two parts: [1] a preliminary selection from among the possible coagulating agents of those that were the most promising decontaminants; and [2] a detailed evaluation of the decontaminating capacity of the selected agents.

Test Solutions

All test solutions were prepared by contaminating sea water, obtained 25 mi out from San Francisco Bay, with radioactive material. The analysis of the sea water used is shown in Table 1. The carrier-free radioisotopes used to contaminate the sea water were: iodine 131, cerium 144, cesium 137,

barium–lanthanum 140, zirconium–niobium 95 . Other contaminants were MFP (mixed fission products) I and MFP II. The analyses of the mixed fission products based on gamma emission are:

MFP I: Cs^{137}, 1.0 per cent; $Ce^{141-144}$, 34 per cent; $Ru^{103-106}$, 29.0 per cent; Zr–Nb^{95}, 11.0 per cent; total rare earths (including Ce), 59.0 per cent.

MFP II: Cs^{137}, 0.3 per cent; $Ce^{141-144}$, 22.0 per cent; $Ru^{103-106}$, 28.0 per cent; Zr-Nb^{95}, 6.0 per cent; total rare earths (including Ce), 66.0 per cent.

TABLE 1

Concentrations of Major Ions Found in Sea Water

Ion	Expected* *ppm*	Found† *ppm*
Chloride	18,980	19,023
Sulfate	2,649	2,652
Bicarbonate	140	—
Bromide	65	—
Sodium	10,557	10,560
Magnesium	1,272	1,310
Calcium	400	405
Potassium	380	390
Strontium	13	6.5

* Ref. 17.
† Sea water from 25 mi out from San Francisco Bay.

Preliminary Survey

The method used for the preliminary screening of possible decontaminants is as follows. Six liters of contaminated sea water are prepared fresh so that a 5-ml aliquot reads about 10,000 to 30,000 cpm in the counter. To an aliquot of 585 ml in a sedimentation cylinder 300 ppm (final concentration) of decontaminant material, which has been stirred vigorously with 5 ml sea water, is introduced. Static settling is achieved through a screen baffle placed about ½ to 1 in. below the surface. The screen baffle minimizes the turbulence of the sea water when the decontaminant is added, thereby providing a uniform settling. The sea water above the screen baffle (which then contains the bulk of the decontaminant) is stirred for a short period with a glass rod, and, when the initial turbulence has subsided, the screen baffle is lifted out, and the floc or particles are allowed to settle. After an hour, a 6-ml aliquot of the sea water is removed from the middle-depth level of the cylinder. The sample is centrifuged and 5 ml is counted and compared to 5 ml of the original centrifuged sample of the contaminated sea water. The counting results are corrected for background and the difference between the original and sample count rates represents the extent of removal. The results obtained give a relative, semiquantitative relationship between the various decontaminants, and facilitate the selection of the more promising materials for further study.

Capacity Studies

Of the materials surveyed, those that had the more promising decontamination capacities were then studied more closely for their decontamination properties. They were used singly and in binary combinations, as listed in Table 2. From 500 ml of radioactively contaminated sea water placed in a 1,000-ml Berzelius beaker, a 6-ml aliquot is removed and centrifuged; 5 ml of the supernatant is used as a comparison standard for the decontamination efficiency. The sea water is then stirred at about 400–600 rpm. A slurry of the selected decontaminant is prepared in 5 ml of sea water and introduced directly into the beaker. After the desired time interval a 6-ml aliquot is removed and centrifuged, and the ra-

dioactivity level of 5 ml of the supernatant is determined. The reduction in activity compared to the centrifuged standard is the actual decontamination.

In the studies involving pH, the radioactive sea water is first stirred with a magnetic stirrer and the pH adjusted to the desired value with either HCl or NaOH. If any pH change occurs after the introduction of the decontaminating agent, it is corrected to the desired value. The pH is observed closely for 15 min and adjusted whenever necessary; meanwhile, the samples are taken at the desired time intervals. At the end of the 15 min, the beaker of sea water is transferred to a motor-driven paddle stirrer where the experiment is carried out to completion.

TABLE 2

Capacity of Decontaminant for MFP I in Sea Water

Decontaminant	Contamination Removed *per cent*	
	1 hr	21 hr
Single		
Sodium orthosilicate	92	96
Magnesium oxide	92	94
Clay, Montmorillonite, Little Rock, Ark.	51	70
Trisodium phosphate	89	85
Coral, Bikini, powder	70	73
Magnesium trisilicate	75	87
Cement, portland	88	94
Bentonite	70	87
Clay, Type 140	68	—
Clay, Montmorillonite, Upton, Wyo.	53	—
Carbon dust	74	—
Binary		
Sodium orthosilicate and:		
Clay, Montmorillonite, Little Rock, Ark.	89	90
Magnesium oxide	90	94
Iron powder	90	—
Coral, Bikini, powder	90	94
Clay, Type 140	—	88
Ferric oxide	84	89
Ferric oxide and:		
Clay, Type 140	76	87
Coral, Bikini, powder	66	89
Magnesium oxide	82	95
Clay, Montmorillonite, Little Rock, Ark.	57	88
Trisodium phosphate and:		
Ferric oxide	88	92
Magnesium oxide and:		
Carbon dust	89	90
Magnesium trisilicate	80	96

Data and Results

The decontamination capacities of the selected materials are shown in Table 2. The results of 1- and 21-hr decontaminations of MFP I in sea water are shown. Table 3 lists the

TABLE 3

Removal of Radioisotopes From Sea Water

Decontaminant	Conc. *ppm*	Time *hr*	Isotope	Removal *per cent*
Cement	300	4.5	I^{131}	13.4
Sodium orthosilicate	300	4.5	I^{131}	14.0
Sodium sulfide	300	4.5	I^{131}	9.7
Ferric oxide	300	4.5	I^{131}	13.6
$Na_3PO_4 + Na_2S$]	300	4.5	I^{130}	8.1
$Na_3PO_4 + Fe_2O_3$	300	4.5	I^{131}	5.5
$Na_4SiO_4 + MgO$	300	4.5	I^{131}	10.3
Trisodium phosphate	30	16.0	$Ba–La^{140}$	67.0
Sodium orthosilicate	30	12.0	Ce^{144}	98.0
Clay, Montmorillonite, Little Rock, Ark.	30	21.0	Ce^{141}	26.0
Coral, Bikini, powder	30	22.0	$Zr–Nb^{95}$	62.0
Sodium orthosilicate	30	1.0	Cs^{137}	0.5

decontamination capacities of several coagulants for radioisotopes I^{131}, $Ba–La^{140}$, $Zr–Nb^{95}$, Ce^{144}, Cs^{137}. The behavior of silicates of different Na_2O-SiO_2 ratios, in which the decontaminant is measured in terms of its silica content, is given in Table 4. The decontamination difference, owing to floc preparation of sodium orthosilicate in distilled water and in sea water, is shown in Fig. 1. Sodium orthosilicate decontaminations, measured at 40 min and taken at different pH values, are plotted in Fig. 2, and the effect of the time and pH variables on the decontamination for 100 ppm of the same silicate are given in Fig. 3. The decontamination rates of the various sodium silicates are plotted in Fig. 4. The effect of sodium orthosilicate concentration at constant pH is presented in Fig. 5.

The reproducibility of the procedure was determined by taking six replicate

TABLE 4

Removal of MFP II From Sea Water by Various Sodium Silicates

Na_2O-SiO_2*	pH	Removal *per cent*	Floc Type	Relative Floc Volume	State of Silicate
2.0	8.9	85	very heavy	0.10‡	solid
1.5	9.0	84	medium	0.50	solid
1.0	8.9	86	heavy	0.10	solid
1.0†	9.0	84	medium	0.30	solid
0.625	8.4	78	light	0.10	liquid
0.500	8.3	80	medium	0.50	liquid
0.417	8.3	77	light, sand-like particles	trace	solid
0.417†	8.3	77	very little	trace	liquid
0.325	8.3	75	little	0.10	liquid
0.320	8.2	74	very little	0.10	liquid
0.320†	8.2	74	none, sand-like particles	trace	solid
0.267	8.1	71	very little, sand-like particles	trace	liquid

* Based on 100 ppm SiO_2 (40-min stirring).
† Different silica contents.
‡ 50 ml of floc volume in 500 ml of sea water.

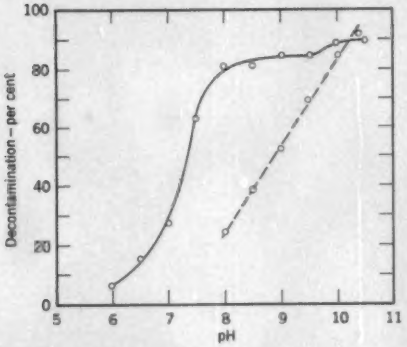

Fig. 1. Decontamination Difference Owing to 100-ppm Na_4SiO_4 in MFP II–Contaminated Sea Water

The solid curve represents decontamination by the floc prepared with sea water; the dashed curve represents decontamination by the floc prepared with distilled water at the same pH values. The time for these decontaminations was 20 min.

samples from a sodium orthosilicate decontamination of MFP-contaminated sea water. These samples were counted long enough to obtain more than 10,000 counts, giving a standard error in counting of less than 1.0 per cent. The six sample net counts were: 33,483; 33,939; 33,635; 33,454; 33,601; 33,669. The standard deviation was 173 counts absolute, or 0.5 per cent.

Discussion

The decontaminants used in the capacity studies (Table 2) are the coagulants remaining after the elimination of most of the materials in the preliminary survey. Selection of the decontaminants for the capacity study was based on observations made in the preliminary survey and the following four considerations: [1] relative decontaminating capacity per unit weight of material; [2] cost of material; [3] rate of floc formation; and [4] other characteristics, such as floc density and floc solubility in sea water.

Table 2 shows that only a slight increase in the removal of radioactivity occurs with prolonged contact time, and for sodium phosphate there is a gradual decrease in the decontamination after the initial formation of the floc. This behavior was also noted by Carritt and Goodgal (*4*) in their study of strontium decontamination using phosphate floc at high pH. They attributed the decrease to the absorption of carbon dioxide from the air and the consequently increased solubility of the phosphate. Furthermore, a binary system of floc of similar total coagulant concentration is no more effective than a single floc of the same material.

The studies on the decontamination of single radioisotopes in sea water pointed out that appreciable removal of radioactive multivalent cations (Ba–La, Ce, Zr–Nb) is achieved, but decontamination of monovalent cations (Cs^{137}) or anionic contaminants (I^{131}) is quite poor (Table 3), although with iodine, 13–14 per cent removal is obtained with Portland cement, iron oxide, or sodium orthosilicate, in an excessive concentration of chlorides.

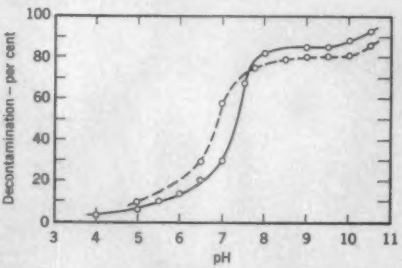

Fig. 2. Decontamination of MFP II–Contaminated Sea Water Owing to Na_4SiO_4

The solid and dashed curves represent decontaminations with 100 ppm and 1,000 ppm Na_4SiO_4, respectively. The time for these decontaminations was 40 min.

Other workers (*2–4, 6, 18, 19*) have reported varying success in the removal of radioiodine from municipal and river waters. Eden and others (*20*) reported a significant improvement in I^{131} removal by adding a little silver nitrate before coagulation and filtration.

Silicate Study

Generally speaking, under the conditions employed, these experiments have shown that sodium orthosilicate is the best single coagulating decontaminant among the materials examined. The use of activated silica as a coagulant aid has been successfully applied to municipal water treatment processes (*21–23*), and the advantages offered by a silicate floc could be beneficial in the removal of radioactivity from sea water. A more extensive study was therefore undertaken.

The effect of floc preparation is shown in Fig. 1, based upon a pH study using sodium orthosilicate as the floc. One set of data is plotted using the silicate dissolved in 5 ml of distilled water before addition to the MFP II–contaminated sea water; the other plot shows the silicate slurried in 5 ml sea water. The graph shows the importance of preliminary floc preparation, which has a significant influence on the decontamination. The silicate dissolves readily in distilled water, giving a clear solution, whereas in sea water a cloudy flocculation takes place immediately, and gelation starts. This flocculation is beaten to a fine slurry with a mechanical stirrer before it is added as a decontaminant. At the end of 20 min decontamination time at pH 8, the sea water floc is nearly four times as efficient as the distilled-water floc. The advantage is not sustained over the pH range studied, however, for at pH 10 the flocs give nearly equal decontaminations.

Many workers (*3, 4, 18*) have shown that the optimum decontamination is obtained at a high pH (about pH 10 or higher) in domestic water studies using conventional water treatment chemicals. Likewise, for sea water the

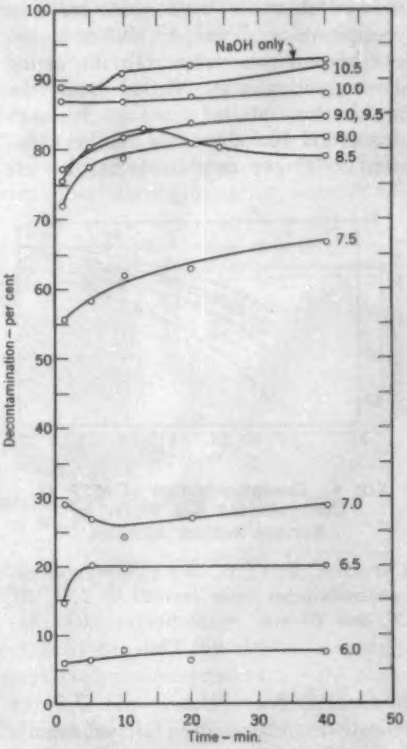

Fig. 3. Decontamination of MFP II–Contaminated Sea Water at Varying pH

The curves represent decontaminations of MFP II-contaminated sea water at the pH indicated using 100 ppm Na_4SiO_4.

results of this study show that decontamination takes place best above pH 8, using sodium orthosilicate. Figure 2 gives a comparison of removal of radioactivity from MFP II–contami-

nated sea water using two different concentrations of sodium orthosilicate. The tails on the plot starting at pH 10 are caused by the hydroxide precipitation of calcium and magnesium, whose ions are abundantly found in sea water. A precipitation check on sea water showed that the hydroxides start to precipitate at about pH 10.3 and persist beyond this value. In the actual decontamination by NaOH alone, the broken line plotted in Fig. 3 shows that at pH 10.5 there is a decontamination of 90 per cent or better by the

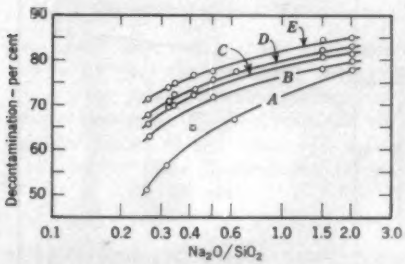

Fig. 4. Decontamination of MFP II–Contaminated Sea Water by Various Sodium Silicates

Curves A, B, C, D, *and* E *represent decontaminations over periods of 1, 5, 10, 20, and 40 min, respectively; SiO_2 content, 100 ppm.*

hydroxide floc. Below pH 7.5 the silicate decontamination falls off rapidly from 65 per cent to approximately 8 per cent at pH 6. Also there is a decreasing quantity of floc formation until at pH 6 there is no visible floc. Further experiments made at a pH below 5 showed irregular decontaminations of 2–10 per cent. These slight removals of radioactivity are attributed to the precipitation of colloidal silica which can be seen adhering to the bottom of the test beakers. Thus, for practical considerations, the decontamination up to an optimum value is proportional to the amount of floc formed.

The rapidity with which the decontamination occurs may also be seen in Fig. 3. In most cases of controlled pH studies over the range of pH 5–10.5, the equilibrium removal of activity is nearly reached after the first minute for 100 ppm sodium orthosilicate in MFP II–contaminated sea water. The rate of the decontamination starts very high and falls off rapidly after the first minute. Furthermore, Fig. 5 shows that the rate of decontamination is independent of concentration of the silicate beyond 300 ppm, at 1–40-min contact time. Also, beyond this concentration of the decontaminant the time variable becomes inconsequential in the decontamination rate because the maximum decontamination is almost instantaneous and no significant decontamination occurs beyond the first minute.

A concentration gradient study of sodium orthosilicate (Fig. 5) at a controlled hydrogen-ion concentration (pH 8.5) shows that with addition of more than 200 ppm of the decontaminant no appreciable increase in the removal of radioactivity occurs in MFP I–contaminated sea water. Over the range of 20–1,000 ppm of floc studied, 90 per cent decontamination of MFP I is achieved in a single-stage stirring process.

The flocculation characteristics of the different commercial sodium silicates in relation to their decontamination efficiencies for MFP II in sea water are presented in Table 4. The material added is based on a final concentration of 100 ppm of silicon dioxide in sea water. The results show that a better removal of activity is obtained with higher Na_2O-SiO_2 ratios. The effect of the sodium oxide content of

the silicate is shown by pH measurements of each silicate in the contaminated sea water, which ranged from 8.1 for the siliceous type to 9.0 for the alkaline silicates. Earlier it was found that at these hydrogen-ion concentrations there was no hydroxide precipitation and, consequently, no hydroxide decontamination was indicated. There is direct correlation between pH and decontamination, however. The quantity and kind of floc obtained with the silicates are largely pH-dependent and, generally, the floc volume is directly proportional to the decontamination. ratios. The decontamination rates of the siliceous silicates are not nearly as rapid as those of the alkaline silicates; nor are their capacities for MFP II in sea water as great. Among the sodium silicates investigated, the orthosilicate, which has an Na_2O-SiO_2 ratio of 2.0, exhibited the best decontamination characteristics for MFP in sea water.

From the laboratory evaluation of a single-stage stirring process, the possibility of radioactivity removal from highly saline solutions to safe tolerance levels is demonstrated. Greater efficiency in decontamination should be

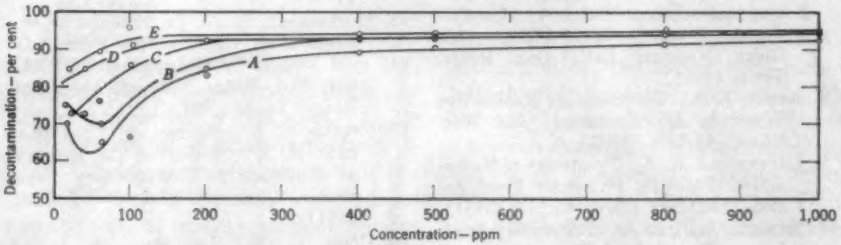

Fig. 5. Decontamination of MFP II–Contaminated Sea Water With Various Concentrations of Na_2SiO_4

Decontamination times for Curves A, B, C, D, *and* E *were respectively 1, 5, 10, 20, and 40 min. pH in all tests was 8.5.*

Qualitatively, the alkaline silicates coagulated in a heavy, voluminous flocculation; the more siliceous silicates yielded very little floc but precipitated as grainy, sand-like particles which, on later examination, proved to be discrete silicon dioxide particles. Nevertheless, the silica particles have shown some decontamination capacity for MFP II; 74 per cent of the activity was removed by a siliceous silicate having an Na_2O-SiO_2 ratio of 1.0: 3.2. Figure 4 shows the relative rates of decontamination and the removal capacities of these various silicates, plotted in terms of their Na_2O-SiO_2 achieved through the use of a multistage coagulation process.

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Determination of Radioactive Iodine in Water and Sewage

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SEVERAL radioactive isotopes of iodine are formed as fission products; they are I^{131}, I^{132}, I^{133}, and I^{135}. Most of these have a short half-life and decay out within a few days (*1, 2*). The isotope of greatest importance is I^{131}, a beta-gamma emitter, which has a half-life of 8.1 days (*2*). It is used widely as a tracer, particularly for diagnosis and treatment in medicine. Although I^{131} has a relatively short half-life, it is considered one of the more hazardous radioactive isotopes because it is concentrated in the thyroid gland upon ingestion. The maximum permissible concentrations (MPC) are given as 0.6 μc (microcuries) for the total body, and 6.0×10^{-8} μc/ml in drinking water (*3*). It is desirable, therefore, to have an accurate analytical method for the detection and determination of this radioisotope in low concentrations in drinking water and in sewage effluent.

Determinations in Drinking Water

To determine small amounts of radioiodine in water, the activity must be concentrated from several liters. Methods involving evaporation are undesirable because they are time consuming and because losses may occur during the evaporation process (*4, 5*). Extraction of free iodine with carbon tetrachloride has been proposed (*4, 5*), but this technique is awkward and complete extraction is impossible unless large volumes of carbon tetrachloride are used. For example, Duncan used a liter of carbon tetrachloride to extract the iodine from 6 liters water, and he recovered only about 75 per cent of the activity (*4*). Two other concentration techniques were considered more promising: [1] concentration by ion exchange; and [2] concentration by precipitation.

Concentration by Ion Exchange

Atteberry and Boyd (*6*) have shown that various halide ions can be concentrated and separated using a strongly basic anion-exchange resin. Upon the basis of their work, the following experiment was carried out. A column of resin * 2 cm in diameter and 30 cm in height was prepared. This was converted to the nitrate form by eluting with 1 liter of 1*M* sodium nitrate. The column was washed with 2 liters

* Amberlite IRA 400; a product of Rohm & Haas Co., Philadelphia, Pa.

distilled water and then a 4-liter sample of tap water, containing radioactive iodine and 50 mg iodine carrier in the form of potassium iodide, was passed through the column at a rate of about 2–4 ml/min. The column was finally eluted with 1 liter of 1*M* sodium nitrate solution. This solution was treated with silver nitrate, and the resulting precipitate of silver iodide was filtered, weighed, and counted. About 60 per cent of the carrier was recovered. Complete recovery of the activity was attained when correction was made for carrier loss. Although this experiment demonstrated that ion-exchange techniques could be used to concentrate radioactive iodine from water, no further work was done along these lines because precipitation techniques were equally accurate and required much less time.

Concentration by Precipitation

In aqueous solution it is possible for iodine to exist as the iodide ion, I^-, the iodate ion, IO_3^-, the periodate ion, IO_4^-, or as free iodine, I_2. To achieve complete recovery of radioactive iodine it is essential that the carrier and the radioactive isotope be in identical oxidation states. Therefore, a preliminary oxidation or reduction is required.

Attempts were made to concentrate the radioactive iodine by precipitation as insoluble periodates after a preliminary oxidation with sodium hypochlorite. In all experiments, less than 30 per cent of the activity was recovered; hence concentration by precipitation of insoluble periodates is not recommended.

Precipitation of iodine in the form of silver iodide was considered next. Duncan (*4*) recommended precipitation of silver iodide using potassium iodide as carrier. Silver chloride, formed from chloride ions present in water, was removed by treating the resulting precipitate with ammonium hydroxide, leaving a residue of silver iodide, which was counted. This procedure, however, is not accurate unless the other fission products that are coprecipitated with the silver iodide are subsequently removed.

Experiments in precipitating silver iodide directly from water proved fruitless, because a colloidal suspension of silver iodide formed and did not coagulate even when heated. It was decided, therefore, to add an excess of chloride ions along with the potassium iodide; excess chloride ions then would act as a carrier to bring down the colloidal silver iodide. It was found that 1 ml of 6*M* hydrochloric acid would furnish enough chloride ions to coprecipitate the silver iodide in a noncolloidal form. This was used, therefore, as the basis for a method to concentrate the radioactive iodine from water. After removal of the silver chloride by treatment of the precipitate with ammonium hydroxide, the resulting silver iodide was dissolved by the addition of zinc and sulfuric acid. The radioiodine was then separated from other fission products using the extraction method of Glendenin and Metcalf (*7*).

Procedure

The following procedure is recommended:

1. Take a sample of water 3–5 liters in size, note the time of collection, then add the following reagents with constant stirring: concentrated acetic acid until the sample is acid to litmus; 5 ml of 1*M* sodium bisulfite; 1 ml of 6*M* hydrochloric acid; and 5.0 ml of potassium iodide carrier (10 mg/ml I^-). Stir thoroughly and warm 10–15 min

to insure complete reduction interchange of carrier and activity; then add 25 ml of 0.5*M* silver nitrate solution with vigorous stirring. If the precipitate does not coagulate, heat the sample and continue stirring. Let the precipitate settle, and then decant and discard the supernatant. Transfer the precipitate to a 40-ml glass centrifuge tube and centrifuge. Discard the supernatant. Add 10 ml concentrated ammonium hydroxide to the precipitate in the tube. Stir vigorously, and then centrifuge and discard the supernatant. Stir the precipitate with about 20 ml water; centrifuge and discard the supernatant.

2. Add about 0.5 g powdered zinc (zinc dust) to the precipitate; then add 10 ml of 3*M* sulfuric acid and stir *vigorously*. Let stand about 5 min. Filter this mixture, using ordinary filter paper, and catch the filtrate in a separatory funnel and wash the residue with two 5-ml portions of water. Combine these washings with the filtrate in the separatory funnel.

3. Add 5 ml of 1*M* sodium nitrite to the solution in the separatory funnel, then extract the free iodine with two 10-ml portions of carbon tetrachloride. Drain the carbon tetrachloride layer (lower layer) into a beaker and discard the water layer. Pour the carbon tetrachloride solution back into the separatory funnel and add 10 ml distilled water which has been acidified with 1 ml of 6*M* nitric acid. Add 1*M* sodium bisulfite dropwise, with shaking, until the violet color disappears from the carbon tetrachloride layer; then add 1–2 extra drops. Draw off and discard the carbon tetrachloride (lower) layer.

4. Repeat Step 3.

5. Place the water solution in a 150-ml beaker and boil 2–3 min to expel the excess SO_2 gas, then add 10 ml 0.5*N* silver nitrate solution; stir and boil until the precipitate coagulates. Filter by suction (using a small Hirsch funnel) onto a previously weighed filter paper disc. Wash successively with 20 ml each of: water; concentrated ammonium hydroxide; water, again; and acetone. Remove the filter disc and then precipitate. Dry for 10–15 min at 110°C; then cool and weigh.

6. Calculate the percentage recovery of silver iodide *; then count the activity of the precipitate using a well-type, gamma scintillation counter and scaler. Correct the count for recovery of carrier and decay.†

Reagents

Potassium iodide carrier, 10 mg/ml I^-: Dissolve 13.08 g, cp grade, dry potassium iodide in water and dilute to exactly 1 liter in a volumetric flask.

Silver nitrate, 0.5*M*: Dissolve 85 g cp grade silver nitrate crystals in distilled water, then dilute to 1 liter.

Sodium bisulfite, 1*M*: Dissolve 104 g solid sodium bisulfite in enough water to make a 1-liter solution. This solution does not keep more than a week or two.

Sodium nitrite, 1*M*: Dissolve 69 g of solid sodium nitrite in enough water to make a 1-liter solution. This solution keeps only a month or two.

* Five milliliters of the carrier forms 92.5 mg silver iodide.

† If the sample is not analyzed on the same day it is collected, a correction for decay should be made. The following equation is used:

$$A_{(observed)} = A_{(corrected)} \cdot e^{-0.0861t}$$

where t is the number of days elapsed between the times of collection and counting, A is the activity, and e is the base of Napierian logarithms (*2*).

Results

The procedure was checked by adding known amounts of radioactive iodine in the form of potassium iodide tracer solution to 4-liter samples of tap water. Table 1 summarizes the results obtained. The slightly low results may have been caused by incomplete interchange between tracer and carrier. This error, however, is quite small and within the limits of accuracy of any ordinary radiometric method.

Determinations in Sewage

The determination of radioactive iodine in sewage is somewhat more complicated than in water, because all or part of the radioactive iodine may exist as organically bound iodine rather than in simple, ionic form. In the following experiments, therefore, a radioactive iodine tracer, 80 per cent in the form of iodocasein and 20 per cent in ionic form, was added to representative samples of sewage effluent from the Detroit sewage disposal plant.

Various reagents were tested to decompose the organic substances present. The most efficient was sodium hypochlorite in basic solution. This reagent completely decomposed the organic matter and converted the iodine quantitatively to ionic form.

Procedure

The following procedure is recommended:

1. Place a 3-liter sample of liquid sewage in a large beaker, note time of collection, and add the following: 25 ml of 2*M* sodium hydroxide solution; 5.0 ml of potassium iodide carrier (10 mg/ml I^-); 25 ml of commercial sodium hypochlorite solution (about 5.2 per cent NaOCl). Boil the solution for 2 hr, then neutralize the base with glacial acetic acid (use litmus paper to test), and add 1–2 ml excess of the glacial acetic acid.

2. Add 1*N* sodium bisulfite dropwise with vigorous stirring until a drop of the sewage mixture quickly clarifies dilute potassium permanganate solution. Add, with stirring, 25 ml of 0.5*N* silver nitrate solution followed by 2 ml of concentrated nitric acid. Let the precipitate settle and then decant off the supernatant. Pour the

TABLE 1

Recovery of Radioactive Iodine From Tap Water

Iodine* Recovered *mg*	Gravimetric Recovery *per cent*	Activity			
		Added *cpm*	Recovered *cpm*	Corrected for Gravimetric Recovery and Decay *cpm*	Recovered *per cent*
28.9	57.8	6,780	3,762	6,512	95.9
25.2	50.4	2,696	1,314	2,608	96.6
29.5	59.0	8,427	4,707	7,970	94.6
32.2	64.4	2,300	1,514	2,353	102.0
35.0	70.0	0†	0	—	—

* 50.0 mg iodine in the form of potassium iodide was added to each sample.
† Blank sample.

precipitate and remaining liquid into a 40-ml centrifuge tube; then centrifuge and discard the supernatant. Add 10 ml of concentrated ammonium hydroxide to the precipitate in the tube, stir vigorously, and centrifuge and discard the supernatant. Add about 25 ml of distilled water to the residue, stir, centrifuge, and then discard the supernatant.

3. At this point, follow the same procedure as outlined previously under the determination of radioactive iodine in water, starting with step 2, in which the precipitate is treated with powdered zinc and sulfuric acid.

Results

The procedure above was tested by adding known amounts of radioactive iodine to various samples of sewage. The tracer consisted of a mixture of iodated casein and potassium iodide. Approximately 80 per cent of the activity was in the form of iodocasein and the remainder was in the form of ionic potassium iodide. The results are given in Table 2.

Discussion of Results

The results obtained in the analysis of the sewage samples are somewhat better than those obtained with water samples. This may have been caused by a better interchange between tracer and carrier, owing to the preliminary heating and oxidation. All results are well within the limits of accuracy of a radiometric analysis. The interference of other radioactive substances was not studied, because the efficiency of the method had been demonstrated previously by Glendenin and Metcalf (*7*).

TABLE 2

Determination of Radioactive Iodine in Sewage

AgI* Recovered *mg*	Gravimetric Recovery *per cent*	Activity			
		Added *cpm*	Recovered *cpm*	Corrected for Gravimetric Recovery and Decay *cpm*	Recovered *per cent*
65.9	72.7	—†	6	8	—
62.8	69.4	32,959	23,594	33,997	103.1
51.8	57.2	32,945	19,054	33,311	101.1
71.3	78.8	32,092	23,487	29,808	92.9
54.7	60.4	31,023	18,331	30,305	97.7
65.4	72.3	22,003	15,776	21,820	99.2
52.7	58.2	22,020	13,160	22,611	102.7

* 5.0 ml of potassium iodide carrier (9.78 mg/ml I^-) was added to each sample. This would give 90.46 mg AgI.
† Blank sample.

The sewage used contained only a small amount of suspended solids. If sewage contains large quantities of suspended material, it should be filtered before analysis. The solid matter should be dried and analyzed separately by the procedure given in a separate paper (*8*).

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Dispersion of Radioactive Materials by Streams

Jared J. Davis

A contribution to the Journal by Jared J. Davis, Mgr., Radioecology, Biology Operation, General Electric Co., Richland, Wash. This research was performed under Contract No. W-31-109-Eng-52 between the AEC and the General Electric Co.

WITH expansion in the manufacture and use of radioactive materials, the occurrence of radioactive wastes in the biosphere will undoubtedly increase. One of the most important means of dispersion of such materials is provided by streams. The important role of streams is amplified by two factors. The first is the probability that such bodies of water may become receptors of high concentrations of radioactive wastes. The second is the necessity of insuring that they do not contain concentrations of radioactive contaminants that would make the water deleterious to aquatic organisms or otherwise unfit for man's direct or indirect use.

There are several sources of radioactive contamination in streams. They include dissolution of radioisotopes from natural igneous rocks and sediments, effluents from radioisotope-manufacturing operations, wastes from industrial, research, and medical users, accidents involving nuclear-powered apparatus, and fallout from atomic detonations.

Natural Radioactivity

Under natural conditions most bodies of water contain trace amounts of radioisotopes that are derived primarily from radioactive rocks and minerals with which the water has been in contact. Uranium 238, radium 226 and thorium 232 are the most common naturally occurring radioisotopes in water (*1*). The levels of radioactivity from these sources are usually very low. Spiers (*2*) has indicated that the equivalent radium content of river water is about 0.0001 times that of sedimentary rock. In general, igneous rock contains more radioactive material than sedimentary rock. The radium content of igneous rock averages about 1×10^{-12} g per gram of rock (*3*), whereas values in sedimentary rock range from less than 0.04 to 2×10^{-12} g of radium per gram of rock (*1*). In 1951, Love (*1*) reported that the natural radioactivity in normal surface waters of the United States was 3.6×10^{-10} μc/ml to 3.4×10^{-9} μc/ml and in ground waters 5.8×10^{-10} μc/ml to 3.9×10^{-9} μc/ml. The background concentration of radioisotopes in the Columbia River averaged 3×10^{-9} μc/ml during the period 1948–50 (*4*). Highest concentrations of radioactive materials in natural waters occur in waters with high mineral content. For example, Mammoth Hot Springs, Yellowstone National Park, contains 1.44×10^{-6} μc/ml;

Shoshone Springs, Manitou, Colo., has 3.38×10^{-6} μc/ml; Imperial Spring, Hot Springs, Ark., has 9.03×10^{-6} μc/ml; and Curie Spring, Boulder, Colo., contains 2.68×10^{-4} μc/ml (*1*).

The concentrations of radioactive materials in certain streams have been increased severalfold by mining and smelting. Studies of the effects of uranium recovery operations on radioactivity in streams have been reported by Setter and Goldin (*5*), and Tsivoglou and others (*6*).

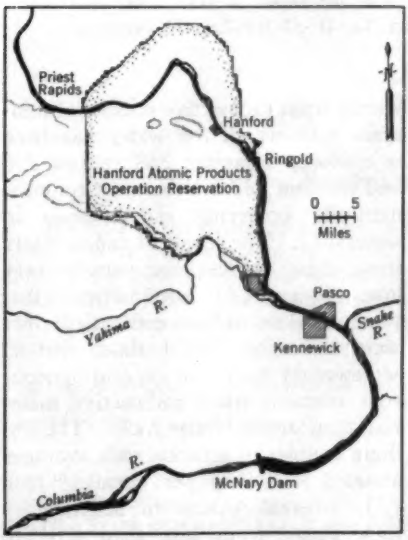

Fig. 1. Environs of Hanford Atomic Products Operation

The portion of the Columbia River shown on the map is the recipient of small amounts of radionuclides from reactor effluents that are pumped into the river from the reactors at Hanford.

Wastes

Wastes from radioisotope manufacturing and atomic-power installations can contribute variable quantities of a large number of different radioisotopes to streams. Examples of streams that receive such products are the Columbia River in Washington, the Ottawa River in Ottawa, and White Oak Creek in Tennessee.

The reactors of the Hanford Atomic Products Operation are located along the main stream of the Columbia River between Priest Rapids and the old town site of Hanford (see Fig. 1). These reactors are cooled by large quantities of water continuously pumped through them from the river. While in the reactors, the water is subjected to high levels of neutron bombardment which transforms some of the dissolved minerals into radioactive isotopes. Additional but smaller amounts of radioactive materials are picked up with the corrosion products that are washed from the inside surfaces of the cooling tubes and from the external surfaces of the "canned" uranium fuel elements. The coolant water that is returned to the river contains small amounts of radioisotopes of many elements, including manganese, sodium, chromium, copper, neptunium, silica, arsenic, zinc, phosphorus, barium, strontium, scandium, cobalt, and others. Many of the isotopes have half-lives of only a few seconds or minutes, but a few have half-lives ranging up to several years.

The Ottawa River is the recipient of small amounts of radioactive contaminants from the Chalk River Project. The radioactive effluents which are discharged into the river include reactor coolant water and some wastes from the processing of irradiated slugs (*7*).

White Oak Creek routinely receives low-level radioactive process wastes from the Oak Ridge National Labora-

tory. The total amounts of mixed radioactive materials that were discharged into the creek system during 1952, 1953, and 1954 were 498, 429, and 254 curies respectively. These wastes were diluted so that the concentration in the stream did not exceed 10^{-7} μc/ml (*8*).

Radioactive wastes from industrial, research, and medical users of radioisotopes will undoubtedly become increasingly common pollutants in streams. Straub (*8*) reported that during 1948–54 the radioisotope shipments from the Oak Ridge National Laboratory increased from 86 to 23,088 c per year. The number of shipments to non-AEC projects increased from 2,633 to 11,395. During the first 5 months of 1957, a total of 57,899 c was shipped to 376 users (*9*). A survey initiated in December 1952, showed that about 41 per cent of 1,027 users of radioisotopes disposed of their radioactive wastes by dilution and discharge into sewers (*10*). At the present time, there are 117 different radioisotopes available for use in the United States and Canada.

Fallout

Fallout from nuclear detonation is a potential source of radioactive contamination to all surface waters. The fission products formed by explosions of nuclear weapons include some 90 different radioactive isotopes ranging over the middle part of the periodic table from zinc to europium. Their half-lives vary from seconds to many years. From data reported by Eisenbud and Harley (*11*), the radioactivity that was deposited on the continental United States between October 1951 and September 1955 averaged about 180 mc of mixed fission products, which included about 6.7 mc of strontium 90 per square mile.

The fission products from fallout that are potentially the most hazardous to biological organisms are those that have the combined characteristics of being accumulated and retained in the bodies of the organisms, having a long half-life, and being abundant. Libby (*12*) has stated that strontium 90 is probably the most important fallout isotope because: it is chemically similar to calcium and is similarly metabolized and concentrated in bone; it has a long biological half-life; it has a long physical half-life of 28 years; and it is produced in high yield in the fission reaction. Strontium from fallout is passed readily along the food chain and its concentrations along the ecological chain tend to reflect a summation of all past fallout (*13*). The fallout isotope of second concern is probably cesium 137, which recently has been detected in human beings and in vegetable and animal foodstuffs (*13, 14*). This isotope is a high-yield fission product, has a physical half-life of 30 years, and is accumulated in organisms via the food web. Information reported to date indicates that its importance to ecological systems may be diminished, however, because it has a relatively short biological half-life (*13, 15, 16*).

It would seem probable that streams could function as concentrators of certain radioactive materials that settle upon watershed areas. Libby (*17*) has shown, however, that samples from the Mississippi, Mosel, Seine, and Danube rivers had less than 5 per cent of the concentration of strontium 90 that was estimated to be in the rains that supplied the rivers. Because it had been observed that most of the strontium 90 deposited by fallout is concentrated in

the top 6 in. of soil, it was concluded that the strontium 90 in the rain was largely removed by the soil before the water reached the river. Perhaps runoff over frozen ground and from snowfields would not provide an opportunity for the strontium to become bound in the soils.

Contaminant Characteristics

Radioactive wastes that may be discharged into streams from the various operations in the manufacture and use

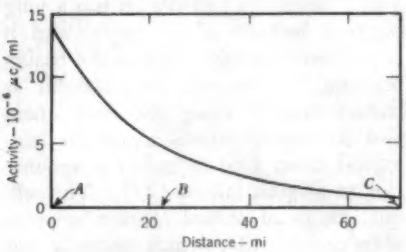

Fig. 2. Distribution of Beta Emitters in Columbia River Water

Point A, *Hanford; Point* B, *Richland; Point* C, *McNary Dam. Owing to the short half-life of most of the isotopes in reactor effluents, the decrease in beta activity is rapid, and little is left by the time the water has flowed south to McNary Dam.*

of radioactive substances, and from accidents involving nuclear-powered apparatus, can include both liquid and solid materials. The dispersion of particulate materials is, of course, influenced by their mass and density. Particulate materials that occur in the coolant water from the Hanford reactors are largely settled out in cribs or in retention basins, which receive the water before it is returned to the river.

The potential extent of dispersion of radioisotopes is also influenced by the lifetime of the isotope. For example (Fig. 2), in the Columbia River, maximum concentrations of radioactive contamination from beta emitters in the water occur near the site of the ghost town of Hanford, which is downstream from all reactor coolant outfalls. Below Hanford, the concentration of radioisotopes decreases rapidly in the first few miles, then gradually declines at a slow rate to the mouth of the river. Preliminary analyses have indicated that plankton taken from the mouth of the river at the end of an outgoing tide during September 1956 contained about 8×10^{-5} μc/g P^{32} (wet weight), 4×10^{-5} μc/g Zn^{65} and 4×10^{-6} μc/g Cs^{137}. The initial rapid drop in radioactive contamination below Hanford is, for the most part, caused by the decay of short-lived materials. The flow time between Hanford and Richland was about 9 hr during the flow stage when the decay sample illustrated in Fig. 2 was collected (*18*). Nine hours would produce a 35 per cent drop in the radioactivity.

The chemical state of the material is undoubtedly important. It is important whether or not the material is in a soluble or insoluble form, and whether or not it is in a form that can be readily metabolized by aquatic organisms.

The temperature of waste products discharged into streams could also possibly effect their dispersion by forming a thermocline, especially if the wastes were discharged into a limnetic environment. The effluents which are discharged into the Columbia are considerably warmer than the river water. Because of the turbulence of the river,

however, there is no significant layering.

Nonbiotic Limnological Properties

Perhaps the most apparent factors that influence dispersion are the morphology and flow characteristics of the stream. The rate and extent of distribution of airborne contaminants mainly depend upon the form and size of the materials and upon meteorological conditions, which are highly variable. When similar materials enter a stream their initial dispersion pattern is relatively constant and defined by the watercourse. Exceptions will be discussed later. It is not until the radioactive materials ultimately are discharged into an ocean that they can become distributed by natural physical means over vast areas of the earth's surface. Of course, the stream flow volume influences the concentration of contaminants. Velocity and turbulence effect dispersion by controlling the rates of mixing and travel of the radioisotopes. The influence of stream velocity upon geographical dispersion of radioactive materials is most pronounced for radioisotopes with short radioactive half-lives. This has been explained in the preceding discussion on the effects of isotope half-life upon dispersion. Although there is no temperature stratification of the reactor effluents in the Columbia, pronounced channeling of the effluents occurs for several miles below the outfalls because of the velocity of the river (*19*).

Samples of plankton and benthic organisms collected from transects across the Columbia River have shown that the geographical dispersion of concentrations of radioactive materials can be significantly influenced by the water from tributaries and in small localized areas by uncontaminated water from springs and seepage. For example, the reactor effluents are uniformly dispersed across the river in the vicinity of Richland, which is 23 miles below Hanford. However, 62 miles below Hanford, at a station which is 25 miles below the mouth of the Snake River, midge larvae, *Chironomus plumosus* (Linnaeus), collected from the benthos on the side of the river into which the Snake empties, contains only one-third as high a concentration of radioisotopes as samples collected from the other side of the river (*4*). Near the mouth of the Columbia River the distribution of radioactive contamination in water and plankton is influenced by the tides. Net plankton samples collected during September 1956, from the midchannel of the mouth of the river, contained 8×10^{-5} μc/g wet weight when collected on the end of an outgoing tide, and 3×10^{-6} μc/g when collected on the end of an incoming tide.

Various chemical properties of waters that receive radioactive wastes could theoretically influence the dispersion of certain isotopes within them. For instance, the pH and chemical composition of the water could influence the precipitation of such radioactive materials, or the abundance of certain elements could influence the accumulation of some isotopes in biological systems by isotopic dilution. The effectiveness of isotopic dilution in regulating the uptake of radioactive materials by organisms has been discussed by Kornberg (*20*). Preliminary experiments by the author have indicated that when the total phosphorus content of Columbia River water, which averaged about 0.01 ppm phosphorus as PO_4 or 0.003 ppm as

P, was increased to 0.05 ppm P by the addition of stable phosphorus, the amount of phosphorus 32 concentrated in aquatic organisms was reduced by about 50 per cent. This relationship appeared to be linear with additions of up to 1 ppm of stable phosphorus.

Water temperature can indirectly affect the dispersion of radioactive materials that become concentrated in aquatic organisms. The uptake of isotopes of essential elements is largely regulated by metabolic rate, and water temperature is one of the main factors which regulates the metabolic rates of aquatic plants and cold-blooded animals.

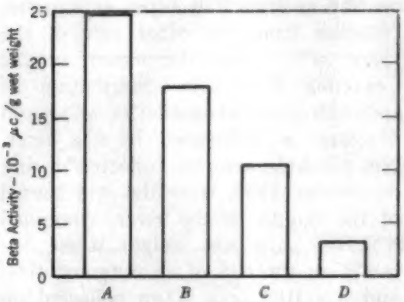

Fig. 3. Total Beta Activity in Organisms From Hanford Station

The data upon which this graph is based were gathered in September 1956. Bar A, *net plankton; Bar* B, *caddis fly larvae; Bar* C, *shiners; Bar* D, *skulpins.*

Accumulation by Organisms

There are many interesting relationships between the Columbia River biota and the dispersion of certain radioactive materials in and from the river. All organisms that are indigenous to the river downstream from the Hanford reactors accumulate radioactive materials. The radioisotope content of the organisms is quite different from that of the water, however. Some of the isotopes are concentrated to many times the concentration in the water, others are not. The average gross concentrations of beta emitters in several forms of river organisms which were sampled from the Columbia River near Hanford during September 1956, are shown in Fig. 3. The four kinds of samples illustrated represent four trophic levels. They are: [1] plankton, which is dominantly phytoplankton; [2] caddis fly larvae (*Hydropsyche cockerelli* Banks); [3] shiners (*Richardsonius balteatus* Richardson); and [4] sculpins (*Cottus asper* Richardson). In this case the decrease of gross beta emitters among organisms in progressively higher trophic levels can be attributed mainly to radioactive decay because the beta particles measured were mostly from P^{32}. Phosphorus is an essential element, readily accumulated by the organisms, but it has a radioactive half-life of only 14.2 days. Zn^{65} produced a considerable amount of beta activity, but of energy so low that only about 3 per cent of it was measured by the standard window Geiger-Muller counters.

The kinds and amounts of specific isotopes that are accumulated by organisms also differ among species. Figure 4 compares the isotopic composition of plankton, caddis fly larvae, shiners, and sculpins which were collected near Hanford during February 1957. The differences in isotopic composition of different species have been attributed to position in food web, life cycles, intraspecific differences in metabolism, chemical composition of tissues, and morphology (*21*).

Phosphorus 32 is the most abundantly concentrated radioisotope in Columbia River organisms; the second most concentrated is zinc 65. Concentrations of phosphorus 32 in aquatic organisms from near Hanford are on the order of 165,000 times that of water for shiners and 370,000 times for caddish fly larvae of the genus *Hydropsyche* (*4*). The avidity for phosphorus 32 in a result of the scarcity of this biologically essential element in the river water. The total phosphorus content of the river water averages about 0.01 ppm as PO_4, the minimum and maximum are 0.003 ppm and 0.044 ppm.

The effect of seasonal changes upon the accumulation of radioactive materials by aquatic organisms has been discussed by several authors (*4, 22, 23*). In the Columbia River the general pattern of the concentration of gross beta emitters in cold-blooded animals is directly related to water temperatures. Highest concentrations occur during the fall months when water temperatures and metabolic rates are highest; lowest values occur during the winter. The seasonal pattern for algae and plankton is closely related to the concentration of radioisotopes in the water and inverse to the river flow rate. Maximum values occur during the low flow stage of the winter and minimum values occur during the spring freshet.

Retention by Organisms

The retention of radioisotopes that have been accumulated in biological systems can significantly alter the distribution pattern that would occur if the dispersion were effected only by such physical means as diffusion and water current. Biological half-life is defined as the time that radioisotopes are retained within the bodies of organisms for metabolic processes. Biological half-lives differ greatly for isotopes of different elements (*24*). There is undoubtedly also considerable variation among species of organisms, as has been demonstrated by the biological half-life of cesium 137, which has been reported to be 140–145 days in man (*13*) and 8–16 days in the rat (*16*).

In experiments on the kinetics of phosphorus exchange in a 10-acre lake (*25*) concluded that the turnover time for the phosphorus in the water was 5.4 days, and for phosphorus, which was in solids including the biota and sediments, 39 days. Rigler (*26*) found the turnover time for phosphorus in the water of a 4.7 ha bog lake was 3.6 days. He also found that 88 per cent of the total phosphorus 32 that he introduced into the lake was lost from the water and plankton at the end of 4 weeks. Only 3 per cent of the original total was lost to the mud and he concluded that about 74 per cent was bound in organisms of the littoral zone.

The effective half-life* of radioactive materials is largely responsible for differences in the geographical distribution patterns of the concentration of total beta emitters among some different kinds of organisms in the Co-

* Time taken for the amount of a radioactive nuclide in tissue of a living organism to decrease to half its initial value due to radioactive decay and biological turnover. The effective half-life is given by the equation:

$$T = \frac{T_b T_r}{T_b + T_r}$$

in which T = effective half-life, T_r = radioactive half-life, and T_b = biological half-life.

lumbia. For example, Fig. 5 shows that in the region of Hanford the plankton is about three times as radioactive as the fish, but 50 miles downstream, and beyond, the fish are the more radioactive. The rapid decrease in the values for plankton can be attributed mainly to the large amount of radioactivity from isotopes of short half-life in the plankton at Hanford, whereas most of the radioactivity in shiners collected from the same location was from radioactive phosphorus, which has a 14.2-day half-life. Even though the specific activity of phosphorus 32 in plankton is about 4 times as high as in the fish, because of the difference of trophic level, the total amount of phosphorus 32 per gram of organism is greater in the fish. The fish contain about 730 ppm of phosphorus as wet weight, as compared to 160 ppm for plankton. Decay curves and radiochemical analyses have shown that most of the beta radioactivity that has been recorded from all kinds of biological samples collected downstream from McNary Dam, which is 70 miles below Hanford, is from phosphorus 32.

Contaminated-Organism Migration

The dispersion of certain radioactive materials within and from a stream may deviate at times from the usual or expected pattern through the migration of organisms. Several examples of transfer of radioisotopes by this means have been observed from studies of the Columbia River.

During the spring and fall, populations of whitefish, *Prosopium williamsoni* (Girard), migrate upstream. Populations that have become radio-

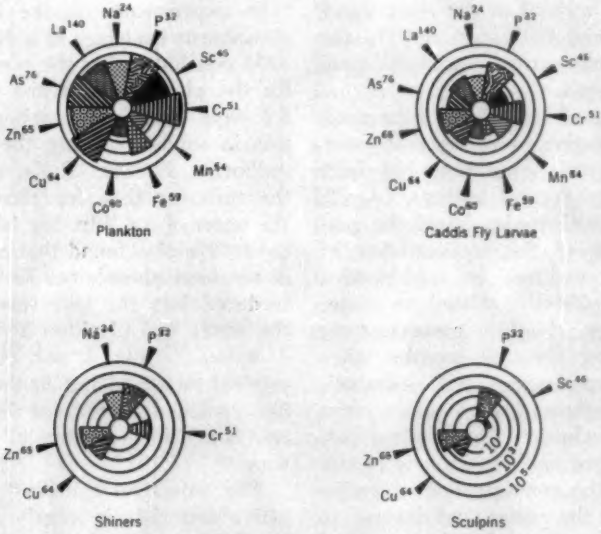

Fig. 4. Radioisotopes in Organisms From Hanford Station

These graphs are based on data gathered in February 1957. Concentrations are in units of 10^{-6} μc/g wet weight.

active by feeding upon aquatic insect larvae from areas within the Hanford reservation move into areas where other species of organisms contain only background concentrations of radioisotopes. The largest migration occurs during the fall when about 85 per cent of the whitefish at a fishing area 8–13 miles upstream from the nearest reactor contain radioactive isotopes in concentrations which exceed background levels (*27*). Slightly contaminated whitefish have been caught as far as 30 miles upstream from the reactors.

Many salmon pass through the Hanford reservations on their migration from the ocean to their spawning grounds. They do not feed during this stage of their life cycle, however, and consequently do not accumulate significant amounts of radioactive material.

Downstream migrations of fish also alter the expected dispersion of radioactive contamination among the biota. For instance, salmon fry consume small invertebrates during their migration down the Columbia to the ocean. While passing through the Hanford reservation they consume organisms which contain radioisotopes and thereby accumulate radioactive materials in their own bodies. Consequently, specimens that are collected downstream from the reservation contain larger concentrations of radioisotopes than are found in other species of fish caught at the same site and that have fed upon the same types of food organisms. Salmon fry and shiners collected at Richland during the spring of 1957 had an average beta activity of 4×10^{-4} μc/g wet weight. At the same time, at Hanford shiners averaged 6×10^{-4} μc/g, and salmon fry averaged 4×10^{-4} μc/g. A young salmon, caught 360 miles downstream from Hanford at the mouth of the river during September 1956, had an average of 1×10^{-4} μc/g muscle (wet weight). This was twice as great as the concentration in samples of any other species of fish at the same location.

Significant amounts of radioactive materials are dispersed from the Columbia by the emergence of aquatic insects. In the region of Hanford, caddis flies (*Hydropsyche cockerelli*) that were attracted to lights of buildings during the summer of 1957 averaged 3×10^{-4} μc/g wet weight and nonbiting midges of the subfamily Orthocladiinae averaged 2×10^{-2} μc/g.

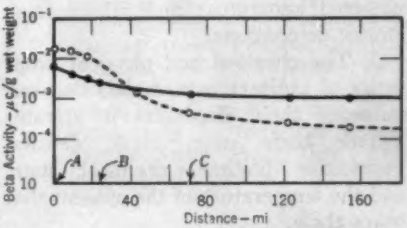

Fig. 5. Geographical Distribution of Radioactivity in Plankton and Small Fish

The solid and dashed curves represent data for small fish and plankton, respectively. Points A, B, *and* C *are, respectively, Hanford, Richland, and Umatilla.*

Hanson and Kornberg (*28*) have reported that waterfowl which have fed from the Columbia in the vicinity of Hanford may have accumulated a concentration of phosphorus 32 in the muscle to 75,000 times its concentration in the river water. Ducks and geese that were banded from populations that inhabited the Hanford region have been sighted in areas ex-

tending from Alberta and British Columbia to California and Oklahoma.

Summary

1. Fresh-water streams provide an important means by which to dispose of radioactive contamination.

2. The main potential sources of radioactive contamination in streams are the mining and smelting of radioactive ores; effluents from atomic-products manufacturing; wastes from industrial, research, and medical users of radioisotopes; accidents involving radioactive materials or nuclear-powered apparatus; and fallout from atomic detonations.

3. The chemical and physical properties of radioactive materials that can influence their dispersion in streams include their state, mass, density, radioactive lifetime, chemical state, and the temperature of the effluent that bears them.

4. Nonbiotic, limnological factors that can influence dispersion of radioactive contamination include stream morphology, flow volume, velocity, temperature, and water chemistry.

5. The biota of a stream can significantly affect the dispersion of radioactive contamination by accumulating and retaining certain radioisotopes, and by spreading the contamination through migration.

Acknowledgment

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Radioactivity in Surface Water

Harry P. Kramer, Dade W. Moeller, and Donald A. Pecsok

A contribution to the Journal by Harry P. Kramer, Chief, Training Program, Dade W. Moeller, Chief, Radiological Health Training Training Program, and Donald A. Pecsok, Asst. Chief Radiological Health Training Training Program, all of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

WITHIN recent years, developments in nuclear science and technology have stimulated widespread application of radioactive materials. Concurrently with these developments, increasing amounts of radioactive wastes are being produced, and disposal of certain of these wastes to the environment is necessary. Unless properly controlled, such disposal can result in contamination of air, water, or food, which, when inhaled or ingested, may present a health hazard to man. The problem of water contamination assumes special significance in that the present major nuclear-industry wastes are aqueous and therefore likely to challenge the quality of our waters. Whether such contamination is purposeful or inadvertent, the prime public-health responsibility is to make certain that the level of radioactivity is neither too high nor rising too rapidly.

Nature of the Problem

Although similar in many respects to ordinary industrial wastes, radioactive wastes have certain unique characteristics:

1. Their radioactivity cannot be neutralized or made nonhazardous through any known chemical, biological, or physical process. Physical removal and containment of the radioactive materials are the only effective methods by which treatment may be accomplished.

2. When discharged into streams, radioactive materials do not exhibit dramatic effects as do most industrial wastes, which, for example, may add color or turbidity or create observable changes in the biological activity of a stream.

3. Precipitation of radioactive materials with other settleable solids to form bottom muds provides storage time for decay. For short-lived materials, this is beneficial. For long-lived materials, however, such deposits can serve as sources of significant waterborne activity during periods of higher flows. The ability of a stream to assimilate sewage and other readily oxidizable organic wastes, has always been regarded as beneficial. The biological concentration of radioactive materials, however, may be detrimental. For example, radioactive materials may be concentrated in plankton, which serve as fish food. Such fish, if later consumed by man, may constitute a public health problem.

4. Typical water treatment systems employed for the removal of nonradioactive pollutants from water do not necessarily provide quality control for radioactive contaminants. Although removal efficiencies of 99–99.9 per cent are attainable for some radioactive contaminants, such efficiencies are not attainable for all radionuclides. In addition, even removals of 99.9 per cent are not adequate when radioactive contaminants are present in high concentrations.

5. Lastly, but of greatest importance, water pollution criteria must be based at the present time on minimal release of radioactive contaminants. Because of the lack of epidemiological experience with waterborne radioactive materials, and because any amount of radiation is potentially damaging to the body, tolerance standards for radiocontaminants have not been established. Rather, upper limits (maximum permissible concentrations) have been formulated, based upon the best technical information available. Examples of maximum permissible concentrations for certain radionuclides are given in Fig. 1. These levels apply to surface waters generally. It is recommended that pollution levels be maintained as far below these upper limits as is practical through reasonable efforts and expenditures.

In view of these unique pollutional aspects, proper control of radioactive wastes at the source is most imperative.

Sources of Radioactive Wastes

The five principal sources of radioactive materials in water are: [1] natural radioactivity; [2] uranium ore refining; [3] reactor operations; [4] reactor byproducts; and [5] weapons tests.

Certain radioactive materials exist in nature. These include uranium and thorium, their decay products, and potassium. Their concentrations (see Fig. 1) in normal surface waters in this country range from 10^{-10} to 10^{-8} μc/ml (*1*).

The United States is one of the world's largest producers of uranium. The refining process separates the uranium and leaves liquid wastes containing all its radioactive daughters including thorium, protactinium, radium, polonium, and bismuth. These wastes are stored in tailing ponds or lagoons from which seepage and direct discharge to nearby streams occur (*2*).

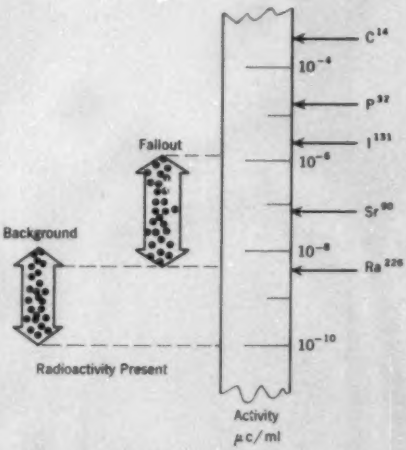

Fig. 1. Radionuclides in Surface Waters and Their Maximum Permissible Concentrations

The double-headed arrows represent total radioactivity from various radionuclides. The fallout arrow, for example, indicates the range of radioactivity that can be directly traced to fallout from nuclear weapons tests.

Radioactive liquid wastes associated with the operation of nuclear reactors

arise from the use of water as a reactor coolant, from reprocessing of spent fuels, and from laboratory, laundry, and decontamination operations necessary for supervision, maintenance, and control. In addition, reactor accidents

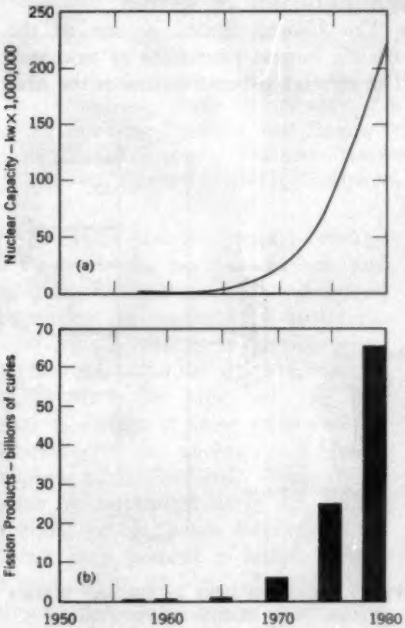

Fig. 2. Forecast of Nuclear Reactor Development and Wastes

Part a *represents a forecast of nuclear capacity to be installed in coming years. Part* b *represents a forecast of future reactor wastes, which can be expected to produce further contamination of surface waters.*

may cause serious contamination of the environment.

Today, water is the most widely used reactor coolant. It is employed in single-pass as well as recirculating systems. Water in either system becomes contaminated with radioactive materials. These arise principally from radionuclides induced in minerals dissolved in the water and from products of corrosion and fission.

In single-pass systems, the water volumes discharged range from a few gallons per minute to several million gallons per day depending upon reactor size. Radionuclide concentrations in such wastes are of the order of 10^{-6} μc/ml.

To minimize the release of radioactive coolants to the environment, most reactors now being designed and built employ recirculating systems. Water quality in such systems is maintained by continuously bypassing a small quantity of the recirculated coolant through ion-exchange purification units. These units may be of the "regenerated-in-place" or "throw-away" type. Where regeneration is practiced, a reduced quantity of a highly concentrated liquid waste results. This is amenable to storage. Where "throw-away" units are used, the waste is handled as a solid.

Nuclear reactors can be operated on a continuous basis only if their fuel is periodically replaced. Currently, old fuel elements are chemically processed at selected AEC installations. This process involves dissolution of the used element, chemical separation of the fission products, and purification of the recovered fuel. Where appropriate, certain valuable nuclides may be recovered from the fission product mixture.

The major portion of the fission products is contained in high-level wastes with concentrations ranging up to several hundred curies per gallon

(10^5 μc/ml). These wastes are stored, principally in underground tanks.

Low-level liquid wastes also result from various steps in the chemical-processing operation, and, under appropriate control, a certain portion of these may be released to the environment. At the Oak Ridge National Laboratory, for example, approximately 500,000 gal of such wastes containing concentrations of activity of the order of 10^{-4} μc/ml are released to the environment daily (*3*).

The predicted growth of power reactor capacities during the next several decades (*4*) is shown in Fig. 2. Also included are estimates of associated quantities of fission products which would result from operation of reactors at these power levels. One hundred days' decay was assumed in calculating these estimates.

The probability of a power reactor accident in which radioactive materials would be released to the environment is estimated to be extremely remote (*5*). The few incidents to date have occurred almost exclusively in experimental facilities. A notable exception was the recent Windscale accident (*6*).

Several thousand universities, hospitals, and research laboratories in the United States are using radionuclides produced by the AEC for medical, biological, industrial, agricultural, and other scientific research, and for medical diagnosis and therapy. The tremendous growth in the number of applications of these materials is depicted in Fig. 3.

A major portion of the distributed nuclides is sealed for use as external sources. These offer little hazard to waters. Unsealed sources, such as I 131 and P 32, may be discharged into sewerage and watercourse systems in appreciable quantities.

The number of bombs detonated in weapons tests throughout the world (*7*) in recent years has been on the increase, as shown in Fig. 4. As a result of these detonations, large quantities of radioactive materials have been introduced into the atmosphere. Carried by the winds, small amounts of these materials are deposited throughout the world. Such deposition is referred to as fallout. One of the most significant fission products in fallout is strontium 90. This nuclide is potentially a most serious internal hazard to man. Its accumulated deposition as recorded in Pittsburgh and New York over the past several years is given in Fig. 4.

Radioactive materials of fallout origin are present in rainfall and in all surface waters in this country. The range of concentrations observed in surface waters is of the order of 10^{-8} to 10^{-6} μc/ml as shown in Fig. 1.

Currently, radioactive materials in surface waters arise principally from background, fallout, and radionuclide users. Streams that pass through uranium-mining areas or near reactors or fuel-reprocessing plants usually contain additional radioactivity. The health significance of these contaminants is dependent upon their nature and magnitude.

Environmental Surveillance

To evaluate the total stress placed upon man by radioactive materials, levels in all phases of his environment must be determined. Current surveillance programs are directed toward measurements of gross alpha and beta radioactivity. The objectives of these

programs are to determine what contamination exists, to estimate its significance, and to develop baseline data. Such data are needed as a guide in reactor site selection and as a gage for determining how much and how rapidly radioactive wastes are being added to the environment in any given area (*8*). Where gross measurements indicate significant contamination, evaluation of the public health problem requires the determination of the specific contaminating nuclides.

Water monitoring is an important phase of an environmental-surveillance program. Activity levels should be determined for all principal streams. A number of studies have been undertaken to develop suitable assay techniques for gross activities in water. Since most stream samples contain suspended matter, these techniques (*9, 10*) provide for the determination of activity levels in both the dissolved and suspended solids. In the procedure developed, an appropriate volume, commonly 1–2 liters, is passed through a membrane filter. The membrane is then transferred to a tared counting planchet, saturated with ethyl alcohol, and burned. After cooling, the sample is weighed and counted. The filtrate containing the dissolved solids is evaporated to near dryness in a heat-resistant beaker without boiling. The residue is then transferred to a weighed counting dish for final drying, cooling, weighing, and counting.

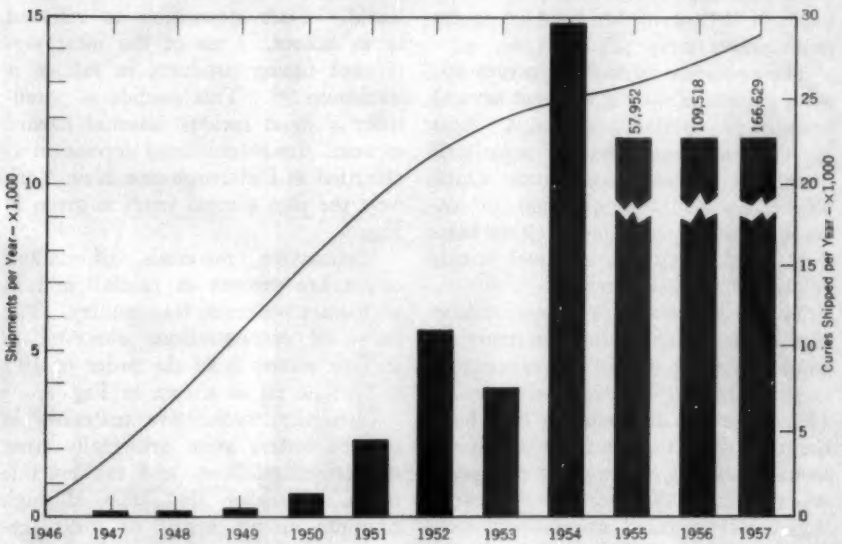

Fig. 3. Radionuclide Distribution and Shipments

The curve represents the growth in the number of radionuclide shipments over the past 11 years. The bar graph represents the growth in radionuclide distribution for the same period.

In conjunction with the determination of activity in the water, samples of bottom deposits or silts and biota may also be investigated (*11*). Bottom deposits or silts are prepared for counting by oven-drying a slurry, representing 50–200 mg on a dry-weight basis, in a tared planchet. Biological samples are prepared similarly, or, if they contain significant amounts of fatty materials, they are further concentrated by wet-ashing using concentrated nitric acid and igniting at 600°C.

As pointed out above, where gross levels approach maximum permissible concentrations, determinations of specific radionuclide concentrations should be performed. Such determinations usually involve separation of the appropriate chemical entities for counting. Specific procedures (*12–14*) for several of the important radionuclides have been developed. Modifications, some of which utilize gamma spectroscopy, are in progress.

For water samples treated as described earlier, the internal proportional counter is recommended (*15*). The sensitivity of this instrument is such that 50–70 per cent of either alpha or beta radiations are detected. On the other hand, end-window Geiger–Muller detectors are not effective in alpha counting and count only 2–20 per cent of the beta radiations emitted from the sample.

Conclusions

The growing applications of nuclear technology generate wastes which challenge the environment. Knowledge of the levels of radioactive materials to which man is exposed is necessary, and environmental-surveillance programs should be instituted to provide this knowledge. Water monitoring constitutes one very important phase of such a program. The instrumentation and methodology required for surveillance programs have been developed.

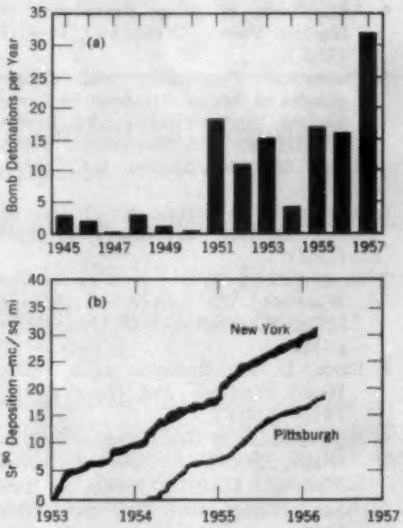

Fig. 4. Weapons Tests and Fallout

Comparison of Parts a *and* b *demonstrates how radioactive deposition from fallout increases cumulatively even though the actual number of bomb detonations may vary considerably.*

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Natural Radium 226 Content of Illinois Water Supplies

Henry F. Lucas Jr. and Frank H. Ilcewicz

A paper presented on Mar. 28, 1958, at the Illinois Section Meeting, Chicago, Ill., by Andrew F. Stehney, Assoc. Chemist & Group Leader, Henry F. Lucas Jr., Asst. Chemist, both of the Radiological Physics Div., Argonne National Lab., Lamont, Ill.

THE concentration of the naturally occurring radioactive elements in surface and ground water sources in Illinois has been studied for many years. In 1916 Scholl (*1*) measured the concentration of Rn^{222} in 68 well and spring water samples, and reported concentrations of 50–2,900 micro-microcuries per liter ($\mu\mu c/l$)* with uranium and thorium undetected.

More recently, Stehney (*2*) reported measurements of the concentration of radium in drinking water from Frankfort on the Main, Germany, finding less than 0.3 $\mu\mu c/l$ Ra^{226}, although more than 300 $\mu\mu c/l$ had been reported previously (*3*). Stehney (*2*) further reported that near Chicago water from surface and shallow wells had less than 0.1 $\mu\mu c/l$ Ra^{226} and that water from wells that penetrate the Galesville sandstone was found to contain 3–8 $\mu\mu c/l$ Ra^{226} and about the same amount of Ra^{224} (Thorium X).

In Illinois in 1950 there were approximately 700 municipalities with public water supplies, of which 200 used surface sources and 500 used ground water sources. In the present survey † samples obtained from 159 municipal water supplies have been analyzed for their Ra^{226} content, and, having been collected from all regions of Illinois, they are believed to be representative of the potable water presently available. Less than 0.2 $\mu\mu g/l$ was found in surface water sources, and less than 1 $\mu\mu g/l$ was found in ground water sources of nonsandstone origin. Concentrations ranging from 1 to 25 $\mu\mu g/l$ were found in water from the three water-bearing, deep sandstone formations.

Sample Selection

Samples were collected from 51 of the 102 Illinois counties, 28 selected at random by drawing of names, and 23 specifically selected to assist in a study of the accumulation of Ra^{226} in humans from different regions of the state. Additional samples were collected in places convenient to the sample collector and in some of the places with unusual geological formations. The locations of the sites sampled are shown in Fig. 1.

Within each of these counties, at least one sample was obtained from each type of source available, with two exceptions: No sample was collected from Clay City, in Clay County, or from Brownstown, in Fayette County. Each source was classified according

* 1 $\mu\mu c = 2.22$ disintegrations per minute.

† Work was performed under the auspices of the AEC.

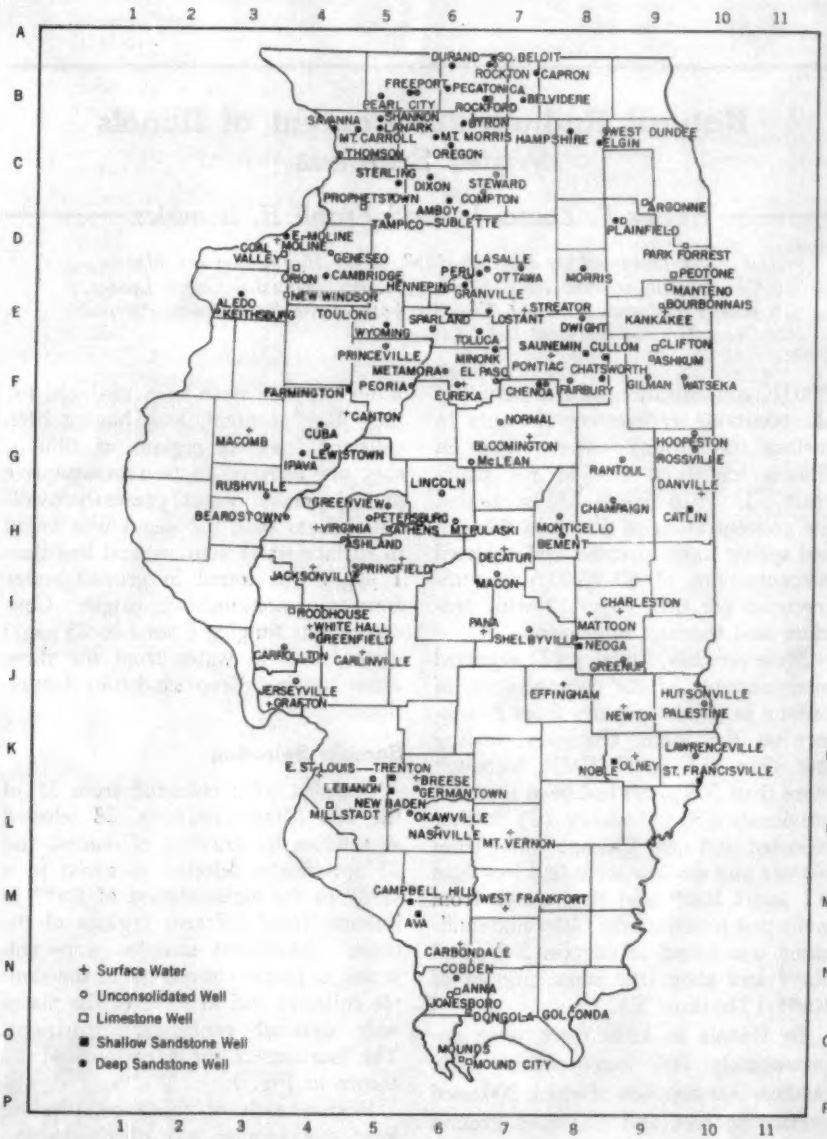

Fig. 1. Illinois Water Sources

Data on Ra^{226} *content for these sources are given in Tables 1–8.*

to the deepest geological formation penetrated as surface, unconsolidated, shallow sandstone, limestone, or deep sandstone (Table 1). This procedure recognizedly places some wells in a deeper classification than that of the principal flow of water. The number is small, however, because drilling usually stops when a satisfactory flow of water is obtained. Each water sample of 0.25 gal each from 57 of the sites were collected. Portions of the 2-gal samples were analyzed for Ra^{226} content while the 0.25-gal samples were sent to the State Water Survey Division for partial chemical analysis. In Tables 2–6, which list the concentrations of Ra^{226} in the various water samples, comments taken from the reports of the division are included. It

TABLE 1

Water Source Classification Guide

Source Grouping	Geological System or Formation	General Description
Surface	—	Lake, river or impounding reservoir
Unconsolidated	Quaternary	Unconsolidated sand or gravel
	Pleistocene	
Shallow sandstone	Pennsylvanian	Shale, coal, shallow sandstone
Limestone	Mississippian	Limestone
	Devonian–Mississippian	Dolomite, limestone
	Devonian	Limestone
	Silurian	Dolomite
Deep sandstone	Ordovician	
	Maquoketa	Dolomite, shale
	Galena–Platteville	Dolomite
	Glenwood	Sandstone, dolomite
	St. Peter	Sandstone
	Shakopee	Dolomite
	Oneota	Dolomite
	Cambrian	
	Trempealean	Dolomite
	Franconia	Dolomite
	Galesville	Sandstone
	Eau Claire	Dolomite
	Mt. Simon	Sandstone
	Pre-Cambrian	
	Fond du Lac	Sandstone

collected was identified by treatment as raw (R), unknown as to treatment (RT), or treated (T). Treated-water samples were collected from those sites where the water was softened or where iron was removed. The addition of chlorine, hypochlorite, or metaphosphate was not considered treatment.

Collection and Analysis

For this survey, 200 samples of 2 gal each from 159 sites, and 59 samples should be noted that the word "typical" means only that the chemical analysis was typical for water from that well.

The water samples were collected in 1-gal bottles * containing 10 ml concentrated nitric acid, which prevents precipitation of residue and loss of radium to the walls. Distilled water

* Duraglas; a product of Owens-Illinois Glass Co., Toledo, Ohio.

samples were collected periodically to provide blanks.

These water samples were analyzed for their radium content by the emanation technique. For each sample, 350 ml was placed in a flask, flushed with radon-free air, and then sealed for a known time, not less than 10 days.

TABLE 2

Concentration of Ra^{226} in Surface Water

Municipality	Location (Fig. 1)	Ra^{226} Concentration* $\mu\mu g/l$
Bloomington	G-6	0.12
Breese	L-6	0.18
Canton	F-4	0.11
Carbondale	N-6	0.06
Carlinville	J-5	0.05
Charleston	I-9	0.11
Danville	G-10	0.14
Decatur	H-7	0.12
East St. Louis	K-4	0.06
Effingham	J-8	0.07
Golconda	O-8	0.15
Grafton	J-3	0.21
Jacksonville	I-4	0.21
Kankakee	E-9	0.10
Macomb	G-3	0.16
Mattoon	I-8	0.12
Moline	D-3	0.08
Mt. Vernon	L-7	0.08
Nashville	L-6	0.09
Newton	K-9	0.10
Olney	K-9	0.11
Pana	J-7	0.06
Pontiac	F-8	0.15
Springfield	H-6	0.03
Streator	E-7	0.12
Virginia	H-4	0.10
West Frankfort	M-7	0.06
White Hall	I-3	0.12

* Estimated error is ±0.02–0.03 $\mu\mu g/l$.

The radon which had developed from the radium in solution was then quantitatively transferred with radon-free air to a charcoal trap immersed in a dry-ice cooled bath (*4*). The radon collected by the charcoal was then transferred by heating and flushing with small portions of helium to an alpha scintillation radon counter (*5*). This system has a sensitivity of 5.45 cpm/$\mu\mu c$ Rn^{222}, a reproducibility of ±1 per cent and a background of 0.08 cpm. Duplicate radon analyses were made on all samples having concentrations of radium greater than 2 $\mu\mu g/l$ and on all nonsandstone samples having more than 0.5 $\mu\mu g/l$. About 1 man-hour was required for each analysis.

Blank values of 0.02 $\mu\mu g$ Ra^{226} were obtained with 350 ml portions of distilled water, which indicates that a correction of 0.06 $\mu\mu g/l$ Ra^{226} should be applied to the water samples. Even smaller values were obtained for some samples collected for this survey, however. Thus, some contamination in the blank samples was suspected and no blank correction has been applied to the values listed in the tables below. If it were necessary to obtain more accurate values for the low-level samples, larger volumes of sample would be used.

Surface Water

Surface waters are obtained from rivers, lakes, or impounding reservoirs. In general the water is filtered, softened, and chlorinated. Samples of such water were analyzed from 28 municipalities, and, as shown in Table 2, the concentration of radium was uniformly low. The mean for all samples was 0.10 $\mu\mu g/l$. Corrected for the blank of about 0.06 $\mu\mu g/l$, the net average radium concentration is about 0.04 $\mu\mu g/l$. This agrees well with the average of 0.03 $\mu\mu g/l$ found by Hursh in similar samples from 35 major cities of the United States (*6*).

Unconsolidated Well Water

Unconsolidated well waters are obtained from sand and gravel deposits of glacial origin. In general, these de-

posits are shallow and only limited amounts of water are available. This source supplies water for the majority of the farms and small municipalities in the central and northern part of Illinois. Large unconsolidated supplies have been developed at Peoria, Beloit, and Rockford.

As shown in Table 3, the radium concentration of unconsolidated well water is low and remarkably consistent. It is believed that water from unconsolidated formations is low in radium content and that high values are obtained by infiltration of highly radioactive water from the underlying St. Peter sandstone formation, either by artesian flow through crevice systems or through nearby deep wells. This latter effect is known from chemical analysis to cause the high value at Chenoa. A concentration of 7.5 $\mu\mu$g/l was found in the nearby deep sandstone well water. Similarly, temperature measurements at Freeport indicate that the water was of the deep sandstone origin. The cause of the high values at Eureka, McLean, and Macon has not been determined. The mean concentration of radium in all raw-water samples excluding the five high values was 0.28 $\mu\mu$g/l.

Shallow Sandstone Well Water

Shallow sandstone well waters are obtained from the Pennsylvania sandstone formation. Very few municipalities have wells that penetrate this formation and, as shown in Table 4, the radium concentrations do not at first appear very consistent. All of the sites north of a line drawn from *K* to *K* in Fig. 1 have low concentrations of radium which are identical with those of unconsoliated wells in the vicinity, however. South of this line five of the six sites sampled have concentrations ranging from 0.9 to 2.0 $\mu\mu$g/l. Thus it would appear that the concentration of radium in water from the shallow sandstone wells will be low in northern and central Illinois and high in southern Illinois.

Limestone Well Water

Limestone well waters are obtained from the Mississippian, Devonian, and Silurian systems and vary more in chemical content than any other type of water. Near Lake Michigan, water of low hardness and residue is obtained, whereas water from wells of the same type at Peoria is not potable and may have 8–10 g/l salt residue.

The concentration of radium in waters from limestone wells is summarized in Table 5. It is believed that water from the limestone formation is rather low in radium content, but that high values are obtained in some cases because of infiltration of higher-activity water from the underlying St. Peter sandstone formation, either by artesian flow through crevice systems or through nearby deep wells. This latter effect probably causes the high value noted for Toulon, because a deep well located 60 ft from the limestone well has no casing to prevent entrance of deep sandstone water into the limestone formation. Similarly, the geology of the region is such that the limestone wells at Coal Valley, New Windsor, and Orion probably obtain water from the underlying deep sandstone formation. The cause of the high values at Clifton and Millstadt has not been determined. The mean concentration of radium in all raw water samples excluding the seven high values was 0.37 $\mu\mu$g/l.

Deep Sandstone Well Water

Deep sandstone well water is obtained from the Ordovician, Cambrian and Pre-Cambrian systems. Wells

TABLE 3

Concentration of Ra^{226} in Unconsolidated Well Water

Location (Fig. 1)	Municipality	Well No.	Sample Type*	Ra^{226} Concentration $\mu\mu g/l$†	Comments‡	Location (Fig. 1)	Municipality	Well No.	Sample Type*	Ra^{226} Concentration $\mu\mu g/l$†	Comments‡
H-4	Ashland	—	RT	0.03		G-4	Lewistown	6, 7, 8	R	0.34	typical
H-5	Athens	1	R	0.47	typical	H-6	Lincoln	1–6	R	0.18	
		—	T	0.18		G-6	McLean	1	R	0.9	typical
H-3	Beardstown	new	R	0.13	typical	I-7	Macon	2	R	1.12	
H-8	Bement	1	R	0.58				2	T	0.27	
J-4	Carrollton	spring	R	0.06	typical	F-6	Metamora	1, 2, 3, 4	R	0.43	typical, iron
H-8, 9	Champaign-Urbana	41, 42, 43, 49, 50, 54	R	0.46		H-8	Monticello	1, 2	R	0.32	
		—	T	0.55				1, 2	T	0.19	typical
F-7	Chenoa	2	R	1.60		H-6	Mt. Pulaski	2	R	0.07	typical
C-7	Compton	west	R	0.41		G-7	Normal	3	R	0.58	typical
E-8	Dwight	4	R	0.52	typical			4, 7, 8	T	0.10	
F-7	El Paso	—	RT	0.14		L-6	Okawville	1	R	0.37	typical
F-6	Eureka	1	R	1.32	typical			1	T	0.15	
		—	T	0.01		J-10	Palestine	—	RT	0.18	
F-8	Fairbury	1	R	0.28	typical	F-5	Peoria	7	R	0.47	typical
		—	T	0.06		H-5	Petersburg	3	R	0.24	typical
B-5	Freeport	5	R	0.65				3	T	0.11	
D-4	Geneseo	—	R	0.25		G-9	Rantoul	2	R	0.17	typical
L-6	Germantown	2	R	0.19	typical, iron low			2	T	0.02	
		12″	R	0.38		B-6	Rockford	7A	R	0.09	
F-6	Gilman	12″	T	0.07		A-7	Rockton	3	R	0.17	
J-4	Greenfield	4	R	0.35		G-10	Rossville	—	R	0.24	typical
J-9	Greenup	4	R	0.11		H-3	Rushville	1	R	0.28	typical
H-5	Greenview	1–50	R	0.08	typical	I-7	Shelbyville	1, 2, 3	R	0.20	typical
G-10	Hoopestown	4	R	0.26	typical	E-6	Sparland	—	RT	0.09	
J-10	Hutsonville	—	RT	0.09		C-7	Steward	1	R	0.23	
J-4	Jerseyville	spring	R	0.10	typical	D-5	Tampico	—	R	0.14	
E-2	Keithsburg	spring	R	0.10	typical			—	T	0.11	
D-7	La Salle	—	R	0.55		C-4	Thomson	3	R	0.14	
K-10	Lawrenceville	6	R	0.16				3	T	0.21	
		6	T	0.16		F-9	Watseka	new	R	0.35	typical
K-5	Lebanon	3	R	0.26	typical	B-8	West Dundee	—	R	0.11	
		3, 4	T	0.04							

* Raw (R), treated (T), type uncertain—may be either raw or treated (RT).
† Estimated error is 5 per cent or 0.02 $\mu\mu g/l$, whichever is larger.
‡ Typical here means that the analysis was typical for that well.

TABLE 4

Concentration of Ra^{226} in Shallow Sandstone Well Water

Location (Fig. 1)	Municipality	Well No.	Sample Type*	Ra^{226} Concentration $\mu\mu g/l$†	Comments‡
M-6	Ava	1	R	1.65	typical
		1, 2	T	0.42	
M-6	Campbell Hill	1	R	1.84	
H-10	Catlin	—	RT	0.25	typical
J-8	Neoga	2	R	0.35	typical
		—	T	0.17	
L-5	New Baden	—	RT	0.09	
K-9	Noble	—	RT	2.05	
F-8	Saunemin	1	R	0.32	
		—	RT	0.42	typical, iron low
K-10	St. Francisville	—	RT	0.88	
L-5	Trenton	6	R	1.08	typical

* Raw (R), treated (T), type uncertain—may be either raw or treated (RT).
† Estimated error 5 per cent or 0.02 $\mu\mu g/l$, whichever is larger.
‡ Typical here means that the chemical analysis was typical for that well.

TABLE 5

Concentration of Ra^{226} in Limestone Well Water

Location (Fig. 1)	Municipality	Well No.	Sample Type*	Ra^{226} Concentration $\mu\mu g/l$†	Comments‡
O-6	Anna	1A	R	0.36	typical
		—	T	0.11	
C-9	Argonne	—	T	0.08	
F-9	Ashkum	1	RT	0.40	typical, iron removed
E-9	Bourbonnais	1	R	0.41	
E-9	Clifton	1	T	1.07	typical, iron low
D-3	Coal Valley	1	R	1.84	
N-6	Cobden	1	R	0.22	typical
O-6	Dongola	1	R	0.13	typical
E-6	Hennepin	—	RT	0.19	
O-6	Jonesboro	1	R	0.15	typical
		1, 2, 3	T	0.19	
E-9	Manteno	—	RT	0.48	
L-4	Millstadt	—	RT	3.72	typical
F-6	Mound City	1	R	0.24	typical, iron low
P-6	Mounds	North	R	0.70	typical, iron high
		North	T	2.20	
E-4	New Windsor	2	R	1.21	
D-4	Orion	1	R	1.49	
D-10	Park Forest	—	R	0.73	
D-9	Peotone	1	R	0.57	
D-9	Plainfield	3	R	0.79	typical, unconsolidated
D-5	Prophetstown	—	RT	0.59	
A-7	Rockton	1	R	0.34	
I-4	Roodhouse	1	R	0.16	
E-5	Toulon	2	RT	5.91	

* Raw (R), treated (T), type uncertain (RT)—may be either raw or treated.
† Estimated errors are 5 per cent or 0.02 $\mu\mu g/l$, whichever is larger.
‡ Typical here means that the chemical analysis was typical for that well.

TABLE 6

Concentration of Ra^{226} in Deep Sandstone Well Water

Location (Fig. 1)	Municipality	Well No.	Sample Type*	Ra^{226} Concentration $\mu\mu c/l$†	Comments‡	Location (Fig. 1)	Municipality	Well No.	Sample Type*	Ra^{226} Concentration $\mu\mu c/l$†	Comments‡
E-3	Aledo	3	R	3.59	St. Peter	E-7	Lostant	—	RT	10.1	St. Peter
C-6	Amboy	2	R	2.12	Galesville	F-7	Minonk	2	R	7.97	St. Peter typical
		—	T	0.16	—	D-8	Morris	3	R	2.37	St. Peter typical
B-7	Belvidere	4	R	0.64	Mt. Simon			4	R	8.20	Galesville typical
B-6	Byron	2	R	4.18	Galesville			3–5	T	6.35	
		1	R	4.80	Mt. Simon	B-5	Mt. Carroll	2	R	2.41	Mt. Simon
D-4	Cambridge	1	R	1.78	St. Peter			3	R	2.76	unknown
A-7	Capron	1	R	0.30		B-6	Mt. Morris	4	R	1.97	Mt. Simon
		1	T	0.11				3	R	0.69	Mt. Simon
F-8	Chatsworth	east	R	0.69	St. Peter	C-6	Oregon	2	R	3.16	Mt. Simon
		—	T	0.50				1	R	3.52	
F-7	Chenoa	1	R	7.50	St. Peter	D-7	Ottawa	8	R	6.60	Galesville typical
		1	T	4.26		B-5	Pearl City	1	RT	1.43	St. Peter
G-4	Cuba	1	R	23.2	St. Peter typical,	B-6	Pecatonica	2	R	2.63	St. Peter
		1	T	11.0	iron high			1	R	0.78	St. Peter
F-8	Cullom	1	R	0.36	St. Peter	D-6	Peru	4, 5	R	4.84	4, St. Peter
C-6	Dixon	3	R	2.94	Mt. Simon						5, Mt. Simon
A-6	Durand	1	R	2.38	St. Peter			4, 5	T	1.23	Mt. Simon
D-4	East Moline	3	R	2.55	Mt. Simon	D-9	Plainfield	5	R	8.24	Galesville typical
C-8	Elgin	1	R	8.5	Galesville	B-6	Rockford	group	R	3.65	Mt. Simon
		1, 2, 3, 5	T	0.66	1, 2, 3 Galesville 5 Limestone			2			
						A-7	Rockton	2	R	2.07	St. Peter
F-4	Farmington	2	R	7.46	St. Peter typical	B-4	Savanna	2	R	3.09	Galesville
B-5	Freeport	4	R	3.61	St. Peter	B-5	Shannon	2	R	17.3	St. Peter
E-6	Granville	2	R	10.2	St. Peter	A-7	S. Beloit	3	R	1.80	Mt. Simon
B-8	Hampshire	2	RT	0.89	St. Peter	C-5	Sterling	1	R	4.02	Mt. Simon
G-4	Ipava	1	R	25.4	St. Peter typical			1–4	T	4.83	
		1	RT	25.4		D-6	Sublette	1	R	0.73	St. Peter
B-5	Lanark	3	R	1.35	Galesville	E-6	Toluca	2	R	7.4	St. Peter typical
		2	R	0.41	St. Peter	E-5	Wyoming	2	R	11.1	St. Peter

* Raw (R), treated (T), type uncertain—may be either raw or treated (RT).

† Estimated error 3% or 0.02 $\mu\mu g/l$. whichever is larger.

‡ Comments of Illinois State Water Survey about samples submitted for chemical analysis, and deepest sandstone formation penetrated.

TABLE 7

Frequency of Various Ra^{226} Concentrations in Deep Sandstone Sources

Approximate Ra^{226} Concentration $\mu\mu g/l$	No. of Sources		
	St. Peters	Galesville	Mt. Simon
2	1	1	2
3	5	1	3
4	2	1	3
5	1	2	2
6	—	—	—
7	—	1	—
8	4	—	—
9	—	3	—
10	—	—	—
11	2	—	—
12	1	—	—
13–16	—	—	—
18	1	—	—
19–22	—	—	—
23	1	—	—
24	—	—	—
25	1	—	—

which penetrate the three water-bearing deep sandstones—namely, the St. Peter, Galesville, and Mt. Simon—are found in the northern third of the state, where they are a major source of municipal and industrial water. These formations underlie the entire area of Illinois with their thickness, depth, and water yield varying greatly from place to place. Because deep sandstone wells are drilled through rock, metal casings are unnecessary except where caving occurs or undesirable water is present. Thus, the water obtained in many of the deep sandstone wells will be from several different geological formations.

The concentration of Ra^{226} in water from the deep sandstone wells is summarized in Table 6. It is believed that high values of radium will be found in water from these formations and low values in wells that obtain their water from the overlying formations. This latter effect is known from chemical analysis to cause the low values at Chatsworth and Cullom. Similarly, a large portion of the flow of water at Capron, Lanark, Pecatonica, and Sublette is known from temperature measurements to be of unconsolidated origin. The well at Hampshire is unusual in that it was drilled to the St. Peter and then plugged at the Galena formation. The major flow of water in this well is of limestone origin. The cause of the low values at Belvidere and Mt. Morris has not been determined. The mean concentration of radium in all raw water samples excluding the nine low values was 6.0 $\mu\mu g/l$.

The frequency distribution of the concentration of radium in water from the three water-bearing sandstones is shown in Table 7. The highest concentration of radium was found for wells that obtained nearly all of their water from the St. Peter sandstone. Such wells at Cuba and Ipava had 23 and 25 $\mu\mu g/l$, respectively. The highest concentration of radium in the water from a well that penetrates the Galesville formation was 8.5 $\mu\mu g/l$ at

TABLE 8

*Summary of Concentrations of Ra^{226} in Illinois Water**

Type of Water Source	Ra^{226} Concentration—$\mu\mu g/l$†	
	Mean	Range
Surface, treated	0.04	0.0–0.15
Unconsolidated	0.27	0.0–1.26
Shallow sandstone		
north, central	0.20	—
south	1.50	0.8–2.00
Limestone	0.56	0.0–1.40
Deep sandstone	5.60	0.1–25.00

* Raw water unless otherwise noted.
† Corrected for blank of 0.06 $\mu\mu g/l$.

Elgin. This well obtains water from both the St. Peter and Galesville formations. The highest concentrations of radium in the water from a well that penetrates the Mt. Simon formation was 4.8 $\mu\mu$g/l at Byron. This well obtains water from the St. Peter, Galesville, and Mt. Simon formations. Thus it seems most likely that the radium found is associated primarily with water from the St. Peter sandstone.

Summary

The concentration of Ra^{226} has been measured in 200 water samples from 159 municipal water sources. Uniform low concentrations of radium were found in the treated water from all surface sources, whereas both high and low values were found in well water sources. High concentrations of Ra^{226} in nonsandstone wells have been correlated with infiltration of deep sandstone water. Concentrations of Ra^{226} from 1 to 25 $\mu\mu$g/l were found in wells obtaining water from the three deep sandstone formations. The highest concentrations of radium are associated with water from the St. Peter formation. Although only a few samples have been analyzed, it appears that the concentration of Ra^{226} in shallow sandstone well water is low in northern and central Illinois and high in southern Illinois.

Average concentrations of Ra^{226} in water from the various source types are given in Table 8. The averages in this table do not include treated-water samples, raw-water samples, or samples known to contain water from a different source type. It is seen that concentrations of Ra^{22} in excess of 2 $\mu\mu$g/l are only found in water from sandstone sources.

The effects of various types of treatment of the water, such as filtration, iron removal, and softening, have not been determined because both raw and treated samples were obtained from a single water source at only twelve sites. All types of treatment appear to reduce the concentration, however.

Acknowledgments

Special thanks are due T. E. Larson and L. M. Henley of the Illinois State Water Survey Division for partial chemical analyses and for assistance in identifying and characterizing the many water samples used in this survey. Thanks are also due H. I. Werth for collecting the samples, and A. F. Stehney, who suggested this work.

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Investigating Ground Water by Analysis of Atmospheric Tritium

Haro von Buttlar

A contribution to the Journal by Haro von Buttlar, Assoc. Prof. of Physics, New Mexico Inst. of Mining & Technology, Socorro, N.M.

THE atmospheric circulation in the arid zones embracing the earth at about 30 deg latitude is such as to produce little rainfall. As a result, these areas have become deserts or semi-deserts with lakes and rivers few in number and generally dry for the greater part of the year. These arid areas, in particular, are dependent almost entirely on their ground water resources. In other locations it has also become increasingly necessary to augment the surface water supply by water derived from the ground.

There are many complicated aspects to the problem of ground water, including:

1. Geological formations which contain ground water
2. Amount of water these formations contain
3. Recharge
4. Size of ground water reservoir
5. Whether ground water moves, and, if so, at what rate
6. Whether different ground water reservoirs are connected
7. Dependability of ground water supply under specified pumping conditions.

Geologists and hydrologists have devoted much time to gathering information on these subjects and have found that the problems are so complex that it has been possible to provide answers for only a few areas. Considering the importance of ground water, there is a definite need for more measurements and different methods of investigation.

A new method of hydrology based on the radioactivity of water due to cosmic-ray action and H-bomb explosions is now being developed. The advantage of this method over most of the conventional techniques lies in the fact that data can be obtained pertaining to the rate of flow of ground water, the fraction of annual recharge, and the age of the ground water with respect to its entry into the ground as rain. Hence, information becomes available which is difficult to secure by other means.

Tritium

The radioactive specimen which is used in the laboratory of the New Mexico Institute of Mining and Technology as a tracer of ground water is tritium, a hydrogen isotope three times as heavy as ordinary hydrogen. It decays radioactively by the emission of a β-particle to form an isotope of helium with a half-life of 12.5 years. Tritium was detected in rain and river water and in wines from different vintages by Willard F. Libby and coworkers at Chicago (*1*). Tritium originates in the

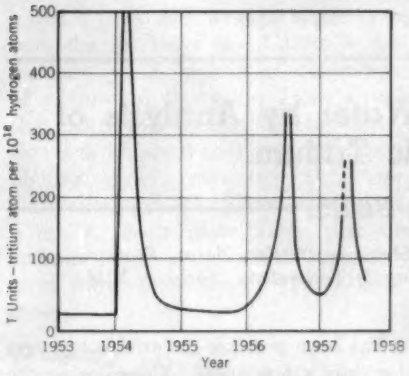

Fig. 1. Tritium Concentration in Rain Water

This figure shows the tritium concentration in rain water as a function of time. The peaks are caused by hydrogen bomb explosions. The dotted line represents a period for which data are uncertain.

atmosphere from the bombardment of air particles with cosmic rays. From the data it is possible to estimate a cosmic-ray production rate for tritium.

Since 1954, thermonuclear explosions have considerably augmented the tritium in the atmosphere. After each explosion, the tritium concentration of rain water exhibits a sharp peak (Fig. 1) which subsequently decays as a result of the air-washing action of the rains. Rivers, which derive their water mainly from rainstorms, show their maximum tritium concentration somewhat later. Similar measurements made on many water samples from locations all over the world confirm that these peaks are not a local occurrence at Chicago but probably extend over at least the northern hemisphere.

The tritium concentrations encountered in natural waters, even shortly

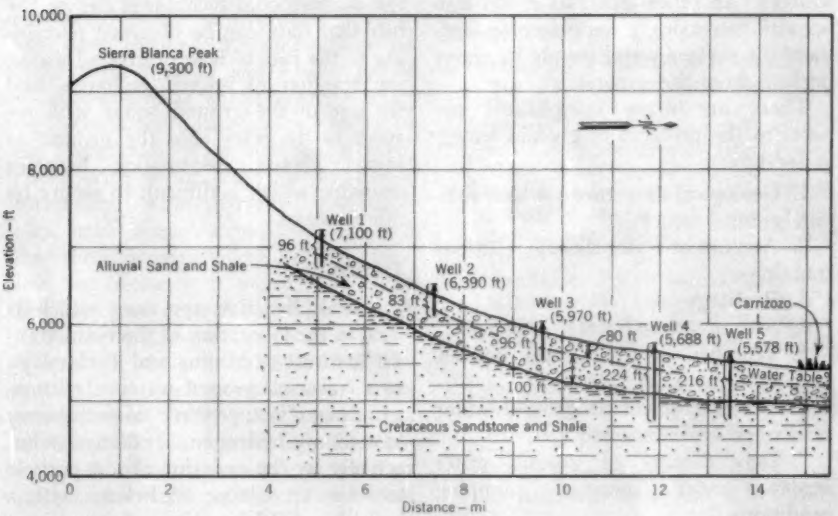

Fig. 2. Carrizozo, N.M., Wells

This figure shows the location and depth of the five wells in the vicinity of Carrizozo, N.M., and the structure of the water-bearing formation. Well 5 is the source of the municipal water supply. The distances in parentheses represent elevation above sea level.

after an H-bomb explosion, are extremely small—a few tritium atoms in 10^{18} ordinary hydrogen atoms. (The concentration of tritium in water is expressed in T units, a T unit being defined as 1 tritium atom per 10^{18} hydrogen atoms.) Only one tritium atom per minute out of 10,000,000 will undergo a radioactive decay process; extremely low activities are, therefore, to be expected in natural water samples. In order to detect tritium, it must be enriched in the water by the process of electrolysis. It can then be measured with a low-level, Geiger-type counting device. The procedures for the detection and measurement of such small tritium concentrations were developed in the Chicago laboratory. The apparatus used in the New Mexico research is similar to that still in operation at Chicago.

Study of Ground Water

The study of the tritium content of ground water was undertaken in the hope of establishing an age scale for ground water with respect to its precipitation as rain. For example, water seeping through the overburden of the Carlsbad Caverns, N.M., was assayed and found to contain an appreciable fraction of water with concentrations higher than those existing before the bomb explosions. Therefore, it may be concluded that it takes about 3 years for this water to percolate through the overburden of the caverns. Socorro, N.M., tap water, on the other hand, is derived from a hot spring near the city, which is probably fed from rain water coming from the Magdalena Mountains, 10 mi distant. It has not revealed bomb tritium as yet, so that the speed of the ground water motion in that area is estimated to be less than 10 mi in 4 years.

In wells near Silver City, N.M., for which data pertaining to the water-table fluctuations are available, a definite correlation between the tritium concentration of the pumped water and the amount of fluctuation was found. Both quantities appear, therefore, to reflect the amount of local recharge. The municipal water supply of Silver City, on the other hand, shows a very low tritium concentration, indicating that little or no recharge takes place

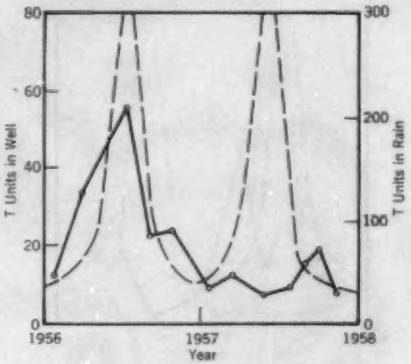

Fig. 3. Well 1

This figure shows T units in the water from Well 1 compared to T units in rain water. Solid line represents T units in well water, dotted line, T units in rain water.

at the source of the water. In other words, at Silver City water is drawn from storage. If the amount of storage is known, the date when the city will have exhausted its water supply can be estimated.

A more detailed study of the tritium concentration in ground water was made in an area south of the town of Carrizozo, N.M. As a consequence of the H-bomb explosions, the recharge of ground water occurring during

times of atmospheric tritium maxima will contain considerably more tritium than during previous or subsequent periods of time. This results in a "spike" of the ground water, which is indicative of its underground age. It may be assumed, for example, that some tritium-rich rain water went underground in the summer of 1954 at the top of a mountain and mixed to a certain degree with ground water already present. Owing to gravity, the water would subsequently flow downslope through permeable beds. A peak tritium concentration will then occur at a well situated near the mountain top a short time after the summer of 1954, but it may take years before the peak reaches a well at the foot of the mountain. The velocity of flow can be calculated from the time delay between the appearance of the tritium peaks and the distance between the wells.

The peak height in the well water, as compared with the peak height in the corresponding rain water, yields some information as to the size of the ground water reservoir. The ratio of the peak maxima indicates by what factor the recharging rain water was diluted with older water in the ground.

The width of the well peak, as compared with the width of the corresponding rain peak, is indicative of the uniformity of the ground water flow. If there are some very permeable underground channels embedded in less permeable strata, the peak at the well site will appear broadened and less well defined.

Wells near Carrizozo, N.M. (Fig. 2), were chosen for the study. Carrizozo has a severe problem in obtaining enough suitable water for its municipal use. The water-bearing formation in the area consists of two major strata. The upper is alluvial sand and gravel, and the lower is a complicated mixture of Cretaceous shales and sandstones, the sandstones containing ground water. The recharging source of water for the alluvial formation is the moun-

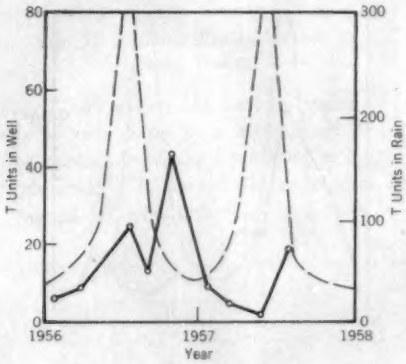

Fig. 4. Well 2

Solid line represents T units in well water, dotted line, T units in rain water.

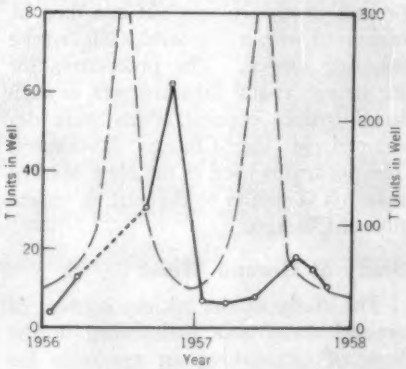

Fig. 5. Well 3

Solid line represents T units in well water, dotted line, T units in rain water.

tain area to the southwest. The source of the recharging water for the Cretaceous beds is not definitely known; it appears reasonable, however, to assume that this water has travelled a long distance before reaching the well sites, and thus will be low in tritium.

The tritium data obtained for the Carrizozo wells indicate that the water pumped from Wells 1, 2, and 3 (Fig. 3, 4, 5), which penetrate only into the alluvial material, has been underground for about 2 years; otherwise, another large peak would have occurred in 1957. The small rise of the tritium concentration in the summer of 1957 can be interpreted as surface seepage resulting from the predominant summer rains in that area. From the time lag between the peaks of Well 1 and Well 2 an approximate velocity of the ground water flow of 50 ft/day can be calculated. Well 4 (Fig. 6), even though it penetrates into the Cretaceous beds, apparently produces a large amount of recent surface water, whereas Well 5 (Fig. 7), the source of the municipal water supply of Carrizozo, appears to produce mainly prebomb water, as indicated by its low tritium concentration. From the peak heights of the tritium concentration of the water in Wells 1 and 2 as compared with the 1954 rain peak, it may be concluded that the water recharging the alluvial formation in 1954 was diluted approximately 90 per cent in the ground.

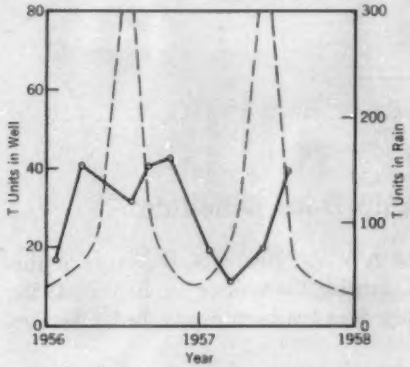

Fig. 6. Well 4

Solid line represents T units in well water, dotted line, T units in rain water.

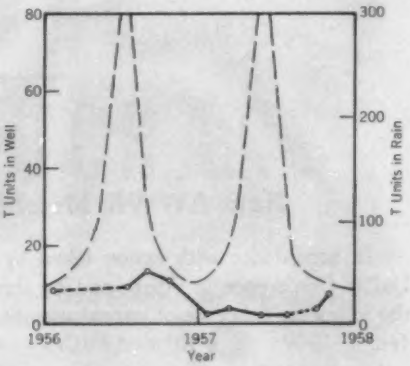

Fig. 7. Well 5

Solid line represents T units in well water, dotted line, T units in rain water. Well 5 is the source of the Carrizozo municipal water supply.

Summary

From these examples it is apparent that the tritium method can very well be developed into a useful hydrologic tool. Its advantages are:

1. Tritium has a convenient half-life, which is comparable in length to the periods of time involved in the ground water circulation.

2. All rain water during certain periods of time has been bomb-spiked

with tritium, so that the tracer is certain to be found at all locations in aquifers receiving recent recharge. This is not the case if a tracer is injected artificially at a point location, because the underground motion of the water may be such that the tracer misses the sampling sites.

3. The radioactive decay particle of tritium has an extremely low energy. The use of tritium, therefore, represents no health hazard to the investigators.

Even though only a few results have been obtained so far, the tritium method has a promising future for ground water studies, provided that further H-bomb explosions do not confuse the tritium peaks of the water.

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New AWWA Membership Dues Schedule

In accordance with action taken by the AWWA Board of Directors at the Dallas Conference in April, and by the Executive Committee on Sep. 8, 1958, the following schedule of annual membership dues has been established, effective Jan. 1, 1959:

Active Member	$ 15
Corporate Member	25
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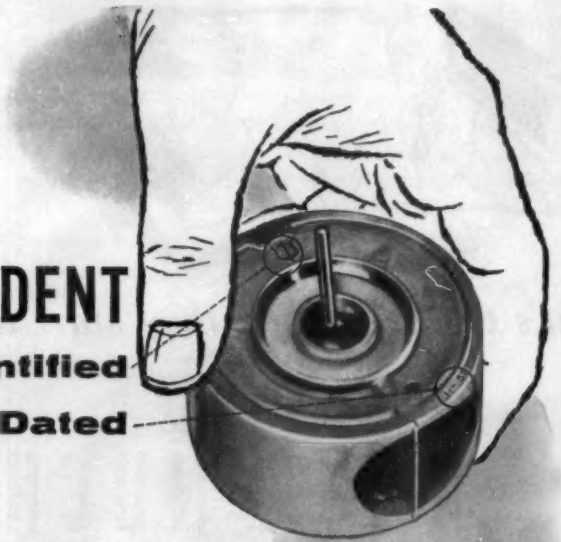

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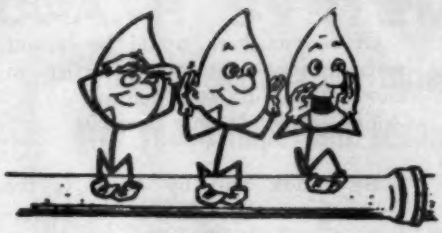


Percolation and Runoff

The 'Do It Now!' program which AWWA launched at the Dallas Convention last April was tied to combating the recession and taking advantage of low interest rates in financing needed construction. Now, with the economy back to boomishness and with interest rates headed upward again, doing it is no less necessary, for despite the surge of doing that the campaign evoked, the backlog of water works projects—that is, projects blueprinted but not yet under contract—is building up at a rate of $650,000,000 per year, with the present total at over $2.6 billion. Unless the industry soon begins doing it at at least twice its present $400,000,000 per year pace, it will never catch up with giving present customers all the water they need, when and where they need it—much less be ready to serve 3,000,000 new water users per year.

The "Do It Now!" campaign will be one phase of the new AWWA Water Works Advancement Program—the logical counterpart of the phase concerned with convincing the public to "Do It" in the first place. "Do It Now!" is being boosted, too, by many of AWWA's members—in their advertising, in their publications, and, of course, in their sales activities. And "Do It Now!" is being made almost mandatory by the current surplus of contractors that has led to what *Engineering News-Record* calls "profitless contracting," the bids having to be too low to be "low."

For improved water service, adequate to meet the growing needs of each community, *DO IT NOW!*

'Just Add Water' are the magic words for almost anything these days. Time was when we could list the "instant" wonders of water and speculate on additional probabilities and possibilities, but now with everything from spaghetti sauce to vichyssoise, from mashed potatoes to orange soda or even beer, available in concentrated "easy to store" form, hardly anything in instantaneity seems remarkable, with the possible exception of "instant ice" in its "throwaway" bottle refrigerator. "Instant ice" comes in a paperboard container big enough to hold a quart of beer or a bottle of champagne; to cool either of these "from, say, 90°F to 45°F" in 15 min, "you just add water."

With this last of our minor problems solved, we feel that the concentrators ought to concentrate on something really worth while for their next project. It was while reading N. J.

(Continued on page 36 P&R)

(Continued from page 35 P&R)

Berrill's *You and the Universe* * that we spotted a natural for instanticizing. Just consider some of Berrill's points:

Water itself, cool water especially, is both the medium of life and the matrix of life and there is nothing anywhere to compare with it. . . . In virtually every way it stands alone in chemical eminence, bathing and penetrating every living cell on Earth. . . . Even a man is nearly three-fourths water, including, of course, his blood, but also his bones. A pinprick anywhere starts a leak; a burn makes a water blister; the sight of good food makes him drool; a sad or sentimental thought brings damp tears to his eyes. . . . Water has been traced through the body and shown to be incorporated into actual living substance, displacing water already present. For a while, at least, water thus becomes alive in a mysterious way, different from what it is under other circumstances. . . . Put together in a proper way, we all turn out to be a rather weak, watery solution of salts and carbon compounds, more or less jellified.

Instant man, of course, easily stored and ready to serve when required. Need a friend? Just add water! Need a television repairman? Just add water! Need an army? Just add water! Of course, there would be one small problem. Not the water itself, because salt water would actually be preferable, but the instillation of the proper characteristics, attitudes, and abilities into the man, either in his instant form or through the water to be added. As a matter of fact, use of instilled water would be more desirable in that it would make possible standardization on a single type of instant personnel, leaving only the supply of characteristics, attitudes, and abilities to be related to long-term inventory requirements.

* Dodd Mead & Co., New York (1958).

Of course there would be instant women, too—considerably easier to handle than just fast women.

The Instant Iceman Cometh!

By crook and by hook is the definitely unfishy fish story of an Atlanta fire hydrant. The crook appeared last spring, running off with the hydrant after he had broken it off in an auto accident. And the hook belonged to vacationing Atlanta water works employee W. B. Kirk, fishing in the Chattahoochee River. Actually, W. B. didn't reel in his catch, but he did land it later. And now cleaned up and serviced, the hydrant is ready to be put to work again. As for W. B., we think he rates some extra fishing time; who knows but what he'll net a butterfly valve next.

Max Suter has retired as principal engineer of the Illinois State Water Survey, Urbana, Ill., which he has served since 1936. From 1940 until last year, Dr. Suter was head of the survey's Peoria laboratory, where his research developed new theories on ground water replenishment. Most recently he has been making a comprehensive study of ground water conditions in the Chicago area.

Watering instructions, attached to a cactus plant purchased at the local florist shop, were expressed in the words of the Cactus Keed. "He say:

Water no mucho once a week
Then I get nice, plump and theek
Water me mucho, then I steenk
Now you know How? I theenk.

As far as the water business is concerned: Trouble with cactus, he no dreenk!

(Continued on page 38 P&R)

C.-A.-P. SYSTEM®

filter gauges and controllers give you 3 important advantages

1. *Positive Controlled Air Pressure*
2. *Instant, accurate measurements of head and flow . . . plus automatic flow control*
3. *Elimination of troublesome cables, piping, stuffing boxes or accessories*

The superiority of the "C.-A.-P. SYSTEM" instruments results from positive controlled air pressure produced by a simple, compact, dependable mechanism. This simplicity contributes to extreme accuracy and rugged construction — economical operation and long life.

The overall advantages to you include greater efficiency throughout your operation and savings in both time and money.

Whether you are installing a new plant or modernizing an old one, investigate the many advantages of INFILCO equipment.
For full information write today for Bulletin 1100.

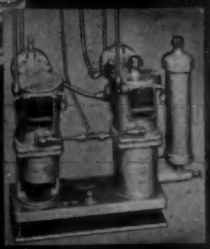
Inquiries and samples are invited on all water and waste treatment problems for municipalities, institutions and industry.

INFILCO

C. A. P. SYSTEM Instruments

Rate of flow controller is accurate and dependable.

Loss of head and rate of flow indicator and recorder is simple and easy to read.



Converters may be mounted in convenient location

Typical operating console is compact and accessible

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General Offices - Tucson, Arizona - P.O. Box 5033
Field offices throughout the United States and in foreign countries

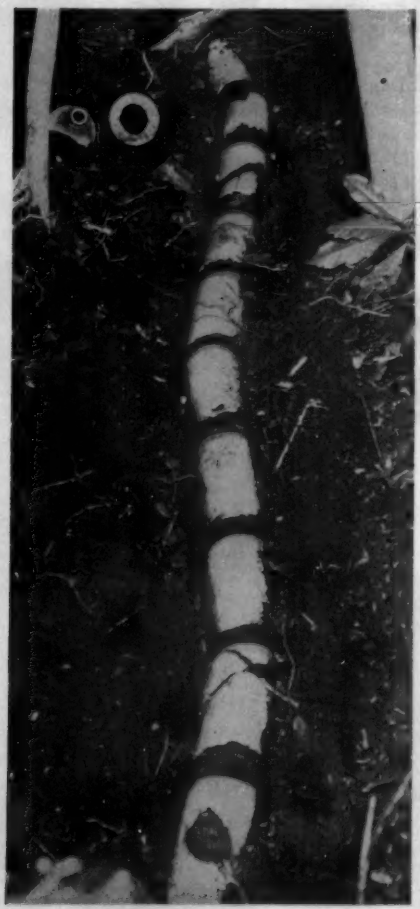
THE ONLY COMPANY impartially offering equipment for ALL types of water and waste processing—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.

57417-A

(Continued from page 36 P&R)

Not just half crocked, but wholly so, is the water distribution system pictured below, part of a 150-year-old pipeline unearthed near Honolulu by Ed Morgan, chief engineer and manager of the Board of Water Supply there. That is, the line was made of crockery jugs about 10 in. in length and 4 in. in diameter, originally used to bring liquor into Hawaii from the Orient. Jointing was accomplished by breaking a hole about 1½ in. in diameter in the bottom of each jug, inserting the neck of the next jug into the hole, and then plastering the union with dense clay. That the line isn't quite straight may be explained by the fact that it extends for a full mile; and even on a contractor 6,500 jugs of Oriental booze must have some effect.

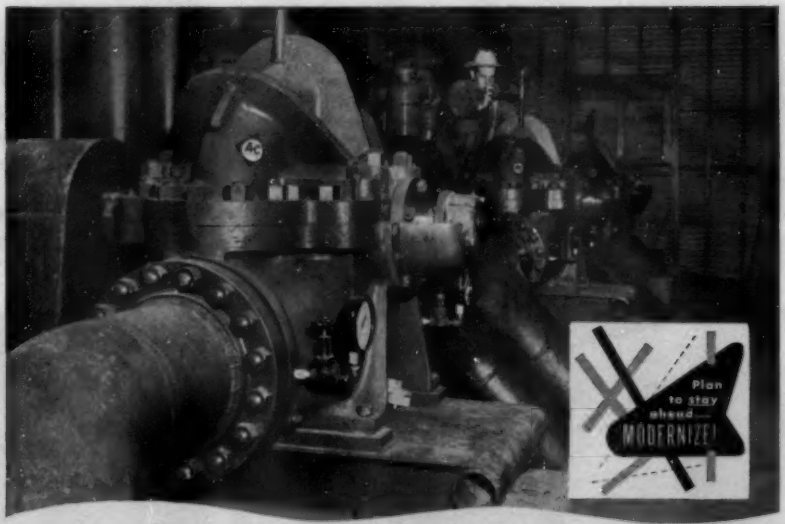
What seems remarkable, of course, is not the fact that the joints lasted as long as they did or that the primitive Hawaiians were so wise in their selection of a corrosionproof material for the line, but that the desire for water should have been great enough to evoke such ingenuity. Or could this have been the beginning of the trend that now has us buying decanters of Old Forester for the do-it-yourself lamp-base instructions that come with it?



ASME announces the election of Glenn B. Warren as president to take office in December. Mr. Warren is vice-president of the turbine division of General Electric Co. Also elected were five vice-presidents, including Harold Grasse, partner, Black & Veatch, Kansas City, Mo. The others named were Charles H. Coogan Jr., Gordon R. Hahn, John W. Little, and Thomas J. Dolan.

Wilbur J. Widmer, assistant professor of civil engineering at the University of Connecticut, Storrs, Conn., has been promoted to the rank of associate professor.

(Continued on page 40 P&R)



Slash municipal pumping costs with nodular iron pump casings

DISTINCT advantages over steel at only a fraction of steel's cost! That's the payoff when Allis-Chalmers pumps with nodular iron casings are applied in waterworks. Corrosion, impact, vibration, oxidation and distortion find better-than-steel resistance in lower-cost nodular iron.

Proof of nodular iron's advantages exists in the Mulvane, Kansas, station of the Augusta-El Dorado Water Association. Here, *without need for costly booster stations,* three Allis-Chalmers pumps in series develop an 870-ft head to provide 5550 gpm over 32 miles of pipelines to two cities and three refineries.

This is only one example of how *you* can benefit from Allis-Chalmers pump experience. For more information, call your nearby A-C office, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS A-5809

(Continued from page 38 P&R)

The 'world's largest testing machine' made its public debut in September at the Research & Development Lab. of the Portland Cement Assn., at Skokie, Ill., near Chicago. The "machine" is actually a three-story structural laboratory, constructed aboveground entirely of precast concrete building units which were tilted or lifted into place by giant rigs and cranes. The building, part of a $3,000,000 expansion, is expected to produce information having a far-reaching effect on design and construction of many types of concrete structures. It adds 22,400 to the 103,400 sq ft of research facilities already at the site, and an additional 35,400 sq ft of test space will be in operation in 1959.

The structural laboratory is unique thick and is joined to an 18-in.-thick primarily because of its testing floor. The top surface of the floor is 24 in. basement floor by a series of 8½-ft-high walls. In cross section, it resembles a large, hollow box-girder bridge. Actually, the floor is built to be much stronger than an ordinary bridge because it acts as a test frame for all the forces applied to specimens in the laboratory. The top surface of the floor is pierced by 690 holes, spaced at 3-ft intervals. To make most tests, steel rods are attached to the test beam or

A 60-ft girder is shown under test in the Portland Cement Assn.'s new structural laboratory. Test forces are applied through steel rods, which can be seen extending from cross pieces over the girder down through holes in the floor. Under the floor are hydraulic jacks which pull down on the rods. This beam was later broken under a total load of 360,000 lb.

(Continued on page 42 P&R)

HIGH-RATE WATER TREATMENT

WITH GRAVER REACTIVATORS®

MEETS THE NEEDS OF HIGHLAND PARK, MICHIGAN

With the growing demand for water by community and industry, the City of Highland Park outgrew its conventional settling plant and old pumping station. To meet its needs, Highland Park built a booster pumping station and installed a high-rate treatment system consisting of two 11 mgd Graver Reactivators. Each of the units is 80 ft. sq. x 21 ft. 6 in. high.

The Graver Reactivator is an up-flow solids-contact unit which incorporates four distinctive design features geared to provide effective clarification. These features are controlled sludge recirculation, low sludge level, separately driven and variable speed impeller and overall sludge removal.

At Highand Park, water supply is drawn from a lake water which forms very light floc and might have been difficult to clarify. But the Graver Reactivators have proved ideal for this water because their design features work together to provide the effective floc formation which results in excellent removal of turbidity.

To-date, the Graver Reactivators have delivered clarified water with turbidities not exceeding 0.3 parts per million. Effluent from the filter plant is so pure that it is difficult to measure accurately.

GRAVER

Municipal Water Treatment Dept. M-421
GRAVER WATER CONDITIONING CO.
Division of Union Tank Car Company
216 West 14th Street, New York 11, N. Y.

Write for the complete story of Highland Park in a new reprint, T-164.

(Continued from page 40 P&R)

girder and extended downward through the holes to connect with hydraulic jacks located in the basement. These jacks pull down on the rods, exerting enormous loads on the test structures above. The floor can withstand test pressures of more than 10,000,000 psi.

That the American way of life was grossly misrepresented by the US exhibit at the Brussels Exposition has

been charged and countercharged on numerous occasions, and we have never become too concerned over the clashes in tastes and theories involved, but the latest report from that front leaves us no alternative but to protest. There is not, we learn, a single drinking fountain to relieve the thirst of the weary visitor. And we daren't even call it a communist trick, for those who have asked for a drink have been told they can get a glass of water at the famous Brass Rail Restaurant in the pavilion.

Not necessarily as evidence of this desiccated situation, but contributing to the impression, one of our Editors Anonymous sent along the adjoining photo of another American in Belgium trying hard, but unsuccessfully, to get some water. The scene is the city square at Bruges and the scenor, a man who usually has better luck with water works. Yes, Harry E. Jordan. It was the dark glasses that fooled you.

Just imagine America without a drinking fountain, though—a land of the thirsty— the uninformed—yes, even unemployed! AWWA demands Brussels spouts!

Hersey Mfg. Co. has opened new Chicago headquarters at 4935 W. Belmont Ave. The 3,000-sq ft building contains facilities for sales, warehousing, and shipping of the company's water meters.

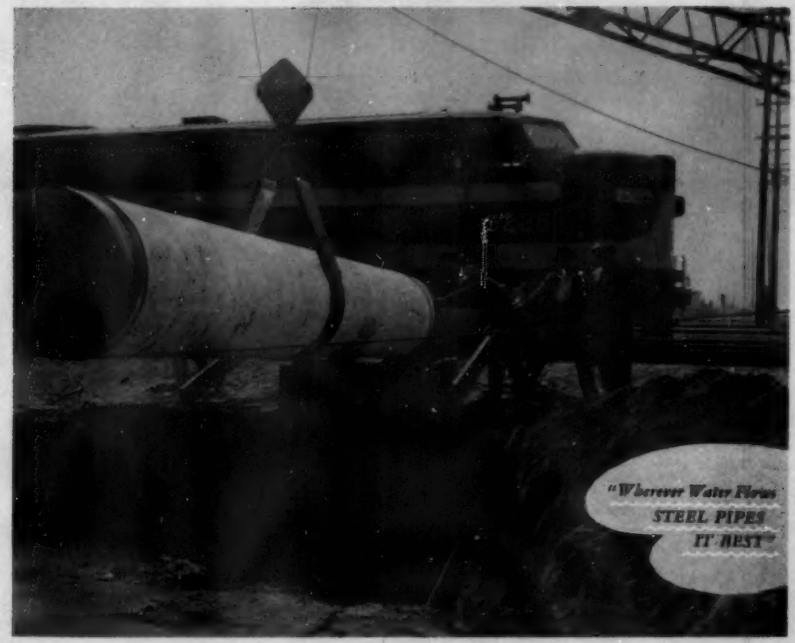
Harry J. Krum has retired as superintendent of the Bureau of Water at Allentown, Pa.

C. E. Lamar is the new assistant sales manager for Southern Pipe & Casing Co., Azusa, Calif. He has been in engineering and sales at Southern for the last 7 years.

E. F. Miller has been appointed manager of municipal water treatment by Graver Water Conditioning Co., New York.

Lewis H. Johnson Jr. will head B-I-F Industries' new regional sales office in Baton Rouge, La. The office is located at 256 Peachtree Blvd.

(Continued on page 44 P&R)



Why does steel pipe get the TOUGH jobs?

Because nothing can match the high strength and ductility of steel pipe. It withstands difficult conditions such as vibrations from rail or highway traffic, unstable foundations, self-supporting or underwater stream crossings, and high pressure lines.

And for *all* of your water line requirements—difficult conditions or normal—you will find that steel pipe offers you the greatest strength, security, and savings.

"WHEREVER WATER FLOWS—STEEL PIPES IT BEST"

STEEL PLATE FABRICATORS ASSOCIATION

105 WEST MADISON ST., CHICAGO 2, ILL.

(Continued from page 42 P&R)

That 'bid and go down' is even more true of poor bridges than of poor bridge is the main point in the engineering profession's argument against the practice of advertising for bids for engineering services on a competitive-price basis. Not that the bridges go down—on the contrary, they are usually expensively overdesigned to compensate for the lack of adequate engineering time—but the ethical standards of the profession do. It was on that basis that the ASCE Board of Direction suspended fourteen of the society's members who bid on a bridge design job for the South Carolina state highway department 4 years ago, and it is on that basis that, particularly, ASCE and the American Institute of Consulting Engineers are working hard to universalize the idea of negotiated engineering contracts.

The negotiation procedure suggested involves:

1. Selecting, from a list of engineers recommended by one of the engineering societies or other employers, one or more engineers to be interviewed separately.

2. Having the client's principal engineer or a small committee of qualified men conduct individual interviews in which consideration is given to the engineer's past experience, reputation, staff, personality, availability for expeditious service, length of time required to complete the assignment, location of the firm in relation to the project, and specialized experience in the field required.

3. Determining the engineer best qualified for the particular work under consideration.

4. Negotiating with the engineer so selected on scope and fee for services of the nature and extent required (permitting him during negotiations to examine existing maps and information and to inspect local terrain and conditions).

5. Checking the reasonableness of the fees to be charged with the engineering society in the particular field or with other employers of consulting engineers.

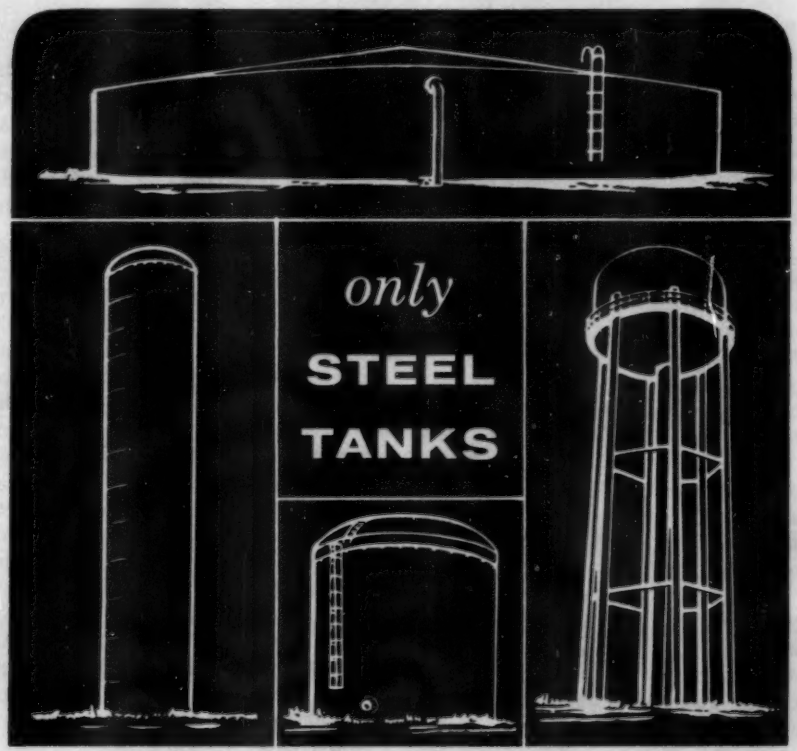
A full statement of the engineering profession's attitude in the matter, which also reviews the courts' support of exemption of engineering services from bidding, is contained in the reprint "Negotiated Engineering Contracts Protect Public Interest" available from ASCE. Simply, it advocates "what price, engineer" over "what price engineer."

Speaking of engineers reminds us to consider who-of we speak. From EJC, recently, came the statement:

> Of major concern to EJC's Public Relations Committee are continued references in the press, radio, TV, advertising, and statements out of Washington, carrying the phrase "science and technology" rather than the more accurate designation "science and engineering." EJC urges its members to help rectify this by calling attention, whenever possible, to the proper phrase (preferred) "engineering and science."

Inclined as we are to give EJC the status of horse's mouth as far as engineering is concerned, we hesitate to accept its urging, more from confusion than disputatiousness. What concerns us is the lack of agreement on a basic definition for either engineering or technology. "Science," it seems, is pretty generally accepted to mean "systematized knowledge." But "technology" is variously defined as "industrial science" or "the systematic knowledge of the industrial arts" or "applied science." And "engineering" ranges from the limits of "the art and science

(Continued on page 46 P&R)



MEET EVERY WATER REQUIREMENT

only steel tanks can meet the many different water storage needs of American communities. No matter whether local conditions can best be served by an elevated tank, a standpipe, or a reservoir—steel will meet all the requirements.

only welded steel construction can offer the combination of strength, tightness, elasticity, economy and long life. These outstanding advantages provide many years of safe, trouble-free water storage.

only steel tanks are built to rigid American Water Works Association Specifications. Established to assure safety and efficiency, these specifications demand maximum protection in design and close control of material and craftsmanship in construction.

"Wherever water is stored—steel tanks it best"

STEEL PLATE FABRICATORS ASSOCIATION

105 West Madison Street
Chicago 2, Illinois

(Continued from page 44 P&R)

by which the properties of matter and sources of power in nature are made useful to man in structures, machines, and manufactured products" to the expansiveness of "applied science and technology."

In speaking of "science and technology," the layman is apparently accepting the definition, "applied science," for "technology." In speaking of "engineering and science" (more properly, if less preferred, "science and engineering"), EJC is apparently accepting the same definition for "engineering." And inasmuch as "science" would seem to include "industrial science," and "systematic knowledge," the "systematic knowledge of the industrial arts," we're just as happy to consign "technology" to technicians and stick to our essentials. Thus, "science and engineering" would mean "systematic knowledge and its application."

On that basis we can follow both the meaning and significance of a recent statement by a Russian educator concerning the 2½-year technical schools from which the Soviet graduated some 225,000 in 1957. "These *technicums*," he said, "make it possible for our scientists and engineers to be scientists and engineers, not technicians." And we can fully appreciate a recent statement by John Van Wazer, assistant director of research for Monsanto Chemical Co., in which he indicated that "the elucidation of organic chemistry gave great impetus to the biological sciences and changed medicine from a subordinate art to a full-fledged branch of engineering." As a matter of fact, we are almost ready to join a urologist friend in insisting that in the future all references to "water works engineering" specify "human" or "nonhuman."

Francis S. Friel, president of the consulting firm of Albright & Friel, Philadelphia, was formally installed as president of ASCE at its annual convention in New York in October. He succeeded Louis R. Howson in the office.

Colorimetric analysis can be performed automatically by a relatively low-cost unit said to be of adequate accuracy (within 2–5 per cent) for normal water plant purposes. The "Chemalyzer," a product of Florida Instrument Co. (division of Milton Roy Co.), 1300 E. Mermaid Lane, Philadelphia 18, Pa., has no moving parts and is powered by the gravity head of the sample. Readings are taken by visual comparison of gradations on a standard color chart with the sample in the instrument's optical cell. An optional photocell unit can also be connected to the optical cell to monitor color change and actuate an alarm or on-off control system.

The Lilliputian leak locater we thought we had found last month (P&R p. 40) would, it appears now, have been nothing extraordinary, even if he had been as extraordinary as we would have thought he was if he were what we supposed him to be. In Detroit, it appears, providing pint-size personnel is the specialty of the Midget Service Co., to whom petite pipeline inspection and repairs are a routine chore. Typical of the accomplishments of Midget's men was the recent inside job of inspection and repair they gave a series of buried 18- and 24-in. air intake lines for the Detroit works of the Aluminum Co. of America. Claustrophobia, anyone?

(Continued on page 48 P&R)

From Fort Ethan Allen, Vt. to Patrick Air Force Base, Fla.

Military installations join the trend to the modern pipe—"K&M" Asbestos-Cement Pressure Pipe with FLUID-TITE Coupling.

Steady, dependable water service—that's a major reason for the trend to "K&M" Asbestos-Cement Pressure Pipe. Once it's installed, you can forget about it. Year after year, the water keeps flowing through . . . clear and unimpeded by tuberculation, corrosion, or electrolysis. The combination of asbestos fibers and portland cement provides a rock-like durability.

K·M
BEST IN ASBESTOS

KEASBEY & MATTISON
COMPANY • AMBLER • PENNSYLVANIA

See the new "K&M" film, "Lifelines of Your Community." It's the exciting, dramatic story of "K&M" Asbestos-Cement Pressure Pipe from manufacturing to installation. Learn how your community can enjoy the finest water service . . . uninterrupted . . . at lowest cost. How you can rid yourself of costly, time-consuming repairs and replacement.

"Lifelines of Your Community" is now available for council meetings, engineer or waterworks association meetings, or to other interested groups. Write to us. We'll make arrangements for showing the film . . . and give you complete information on "K&M" Asbestos-Cement Pressure Pipe.

(*Continued from page 46 P&R*)

After 73 years, Worthington Corp., Harrison, N.J., has retired its winged-scarab trademark in favor of one with a bold, modern look.

Richard H. Ellis, formerly hydraulic engineer with Factory Mutual Engineering Div., has become associated with the consulting firm of Metcalf & Eddy, Boston.

Water weeds can be eliminated from ponds and streams by lining the bottom with an opaque plastic sheet, according to the manufacturer, Bakelite Co., division of Union Carbide Corp. The vinyl cover, which cuts off the sunlight that plants need for growth, is said to be durable and unaffected by prolonged exposure to water. Sheets can be fabricated in one piece to cover 3 acres or more. It is claimed that the liner will not contaminate the water or otherwise interfere with recreational use.

Orangeburg Mfg. Co. has been acquired by Flintkote Co., subject to approval by the stockholders. Orangeburg, which manufactures plastic pipe, among other products, will be operated as a division of Flintkote, a producer of a variety of materials, including containers, floor coverings, paving, and adhesives.

Allis-Chalmers announces the appointment of J. E. Watson Jr. as manager of the New Orleans district. Succeeding him as Miami district manager is W. E. Scott.

A. Stanford Johnson has been promoted to sanitary engineer of the Madison, Wis., plant of Oscar Mayer & Co. He joined the firm in 1956.

The job situation is apparently still favorable for new engineers. According to EJC, 83.5 per cent of the estimated 33,000 June engineering graduates had been hired in May, and by June all had received job offers.

F. W. Montanari, Orsanco staff sanitary engineer, Cincinnati, Ohio, has been elected secretary-general of the Inter-American Assn. of Sanitary Engineering (AIDIS). He was unanimously selected by delegates from 21 countries in the Americas.

William D. Hurst, chairman of commissioners of the Greater Winnipeg Water Dist., has been elected president of American Public Works Assn., the first Canadian named to that office.

Carlton P. Ainsworth has been named assistant to vice-president in charge of manufacturing for Hersey Mfg. Co., Dedham, Mass. He has been with the firm for the past 23 years.

Harlan A. White has been named assistant works manager for Mueller Co., Decatur, Ill. He has been with the firm since 1955.

Sewage works statistics for 1957 are summarized in a report by John R. Thoman and Kenneth H. Jenkins of the USPHS Water Supply & Water

(*Continued on page 50 P&R*)

Designed and supervised by: Casler & Stapleton, Consulting Engineers, Jacksonville, Ill.

For their 30-mile water line . . .

Galesburg, Illinois, saved $894,000 by choosing concrete pressure pipe!

In Galesburg, it's a long way to the town pump. With the local ground water level dropping 3 ft. per year, the nearest adequate supply was the Mississippi River substrata 30 miles away.

For the new pipe line needed, engineers chose concrete pressure pipe—in sizes up to 42" I.D. They saved almost $30,000 per mile, bids showed. They'll get trouble-free service, save on upkeep, too. Concrete has uniformly high strength right from the start—and actually grows stronger year by year.

Add low cost, water-tight joints, permanent high carrying capacity. You can see why more and more communities are using concrete pressure pipe to meet future population needs.

FOR ALL MODERN PIPELINES
concrete

PORTLAND CEMENT ASSOCIATION

A national organization to improve and extend the uses of concrete

(*Continued from page 48 P&R*)

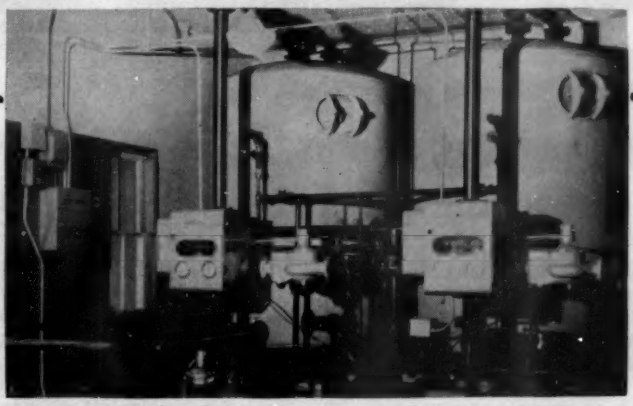
Pollution Control Program staff. The report is based on the 1957 "Inventory of Municipal and Industrial Waste Facilities"—a cooperative activity of the state water pollution control agencies and the USPHS. In that year 11,131 communities had sewer systems serving 98,400,000 persons—an increase of over 2,200 communities and 24,000,000 persons since 1945.

Almost 22,000,000 persons discharge raw sewage to the waterways of the nation, and sewage from an additional 1,900,000 is discharged with treatment of a minor nature. The 76,400,000 persons served by systems connected to treatment plants resided in 8,066 separate communities (7,518 treatment plants). More than 60 per cent of these plants provided secondary treatment. Since 1945 the population served by secondary treatment has increased 100 per cent. In 16 states, the persons served by treatment exceed 90 per cent of the sewered population. This is twice as many states as in 1945. Four of the major drainage basins—Lake Erie, Colorado River, Western Gulf, and California—reported more than 90 per cent served by treatment.

Copies of Publication No. 609, "Statistical Summary of Sewage Works in the United States," may be obtained from the Water Supply & Water Pollution Control Program, US Public Health Service, Dept. of Health, Education & Welfare, Washington 25, D.C.

Charles Clifford Casad, superintendent, Water Dept., Bremerton, Wash., died Sep. 24, 1958, at the age of 69. Born in Seattle, Wash., in

(*Continued on page 52 P&R*)



Iron and Manganese Removal Plus Water Softening . . .
Automatically by Ion-Exchange using Invercarb C-110

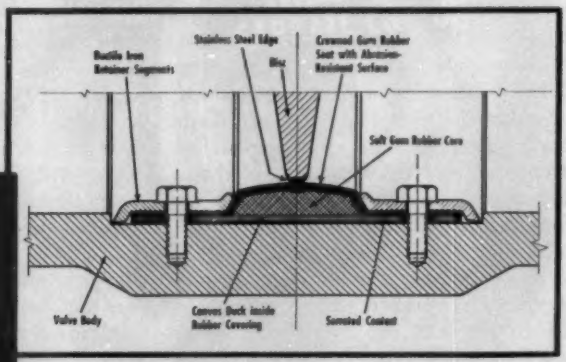
Low in cost—efficient in operation. Send for Particulars.

HUNGERFORD & TERRY, INC.

CLAYTON 5, NEW JERSEY

"WEDGE-LOCK" DESIGN

of Rockwell Butterfly Valves means "Drop-Tight" Closure



This Rockwell "exclusive" meets and exceeds the most rigorous AWWA butterfly valve specifications for tight closure and trouble-free service.

In the valve's most vital part—the valve seat—the stainless steel edged disc seats tightly against the crowned, abrasion-resistant surface of the multi-ply rubber seat. The seat insert is secured to the valve body by serrated contact with the retainer segments. The entire seat can be conveniently removed and replaced at site of installation.

Rockwell AWWA Butterfly Valves assure positive control, minimum restriction of flow, minimum pressure drop and lower maintenance. They require less installation space. Valves are made in full range of sizes, with manual control, cylinder or motor operator.

Many leading water service installations are now Rockwell-equipped. The reason is obvious. Bulletin 581 tells why.

W. S. ROCKWELL COMPANY

2608 ELIOT STREET • FAIRFIELD, CONN.

(*Continued from page 50 P&R*)

1889, he received a civil engineering degree from Washington State College. After gaining considerable renown locally as a semiprofessional baseball player, he became a city employee in Bremerton in 1905. Later he served as city engineer and public works commissioner. He was appointed water superintendent about 1943 and held that position at the time of his death. He was responsible for formulating and carrying through many plans for the development of Bremerton's water supply. Perhaps the most noteworthy result of his efforts is the recently completed 1.3-bil gal Union River dam, which belatedly is being named Casad Dam in his honor. His concern with planning for the future was not limited to water supply but extended to human beings also, as evidenced by his active role in the Boy Scout movement for many years.

A Life Member of AWWA (joined in 1926), Mr. Casad received the Fuller Award in 1943 on nomination by the Pacific Northwest Section. He served as director from that section in 1953–56.

H. Seaver Jones, former president of Centriline Corp., New York, died Sep. 12, 1958. He was 76. Born in Newton, Mass., he was graduated in 1905 from Princeton. He was associated with T. A. Gillespie Co., New York, builders of the Wanaque (N.J.) Reservoir aqueduct, and was vice-president of the firm until its dissolution in 1940. He then became president of Centriline, a post he retained until his retirement 8 years ago. He was a Life Member of AWWA, having joined in 1922.

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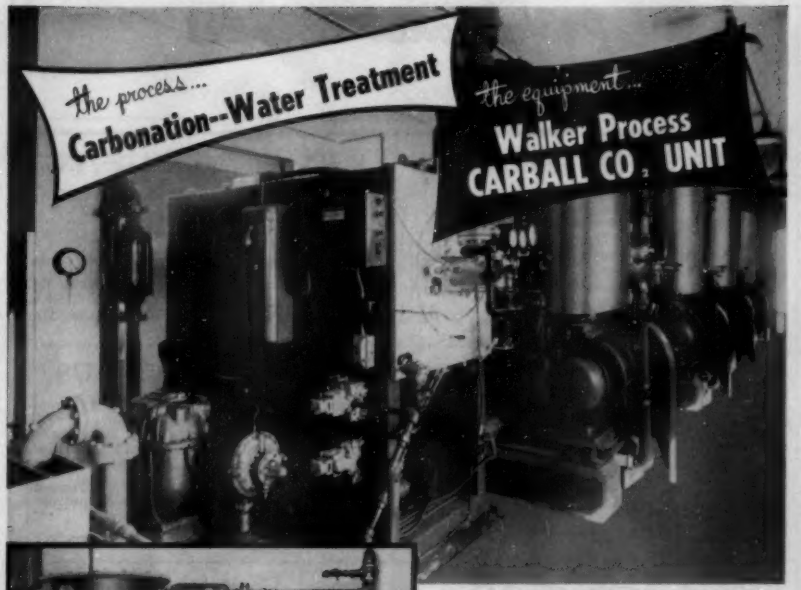

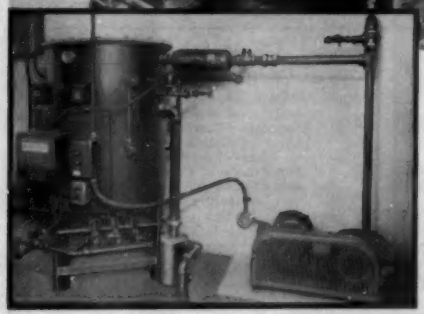

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Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

FILTRATION

Negative Head in Rapid Gravity Filter. K. W. H. LEEFLANG. Proc. Soc. Water Treatment and Examination, 5:175 ('56). In rapid gravity filter, negative head becomes manifest at moment that tot. loss of head has grown to sum of depth of water above bed, initial resistance of well washed filter and factor which depends upon depth of penetration of dirt. In case of rate of flow being equal to or surpassing permeability of sand, this total loss of head amts. to sum of depth of water and sand thickness. No release of gas is possible before min. abs. pressure in bed has sunk below sum of partial pressures which correspond to quants. of gases dissolved in water. Even when abs. pressure decreases beyond this critical value, gases are released with retardation which depends upon phys. character of filtering material. According to expts. with different quants. of dissolved nitrogen and oxygen and both sand and anthracite as filtering material, this retardation is at least 0.5 m water column. As, generally speaking, aerated ground water or surface water will be satd. with nitrogen at atmospheric pressure, oxygen content of water at depth of largest negative head will det. total loss of head at which filter may safely be operated.—*PHEA*

An Analysis of Sand Filtration. W. A. HALL. Proc. ASCE, Paper No. 1276-1-9 ('57). Author has made detailed theoretical anal. in math. terms of action of sand filter in removing suspended matter from water. Such filter is assumed to be homogeneous isotropic porous medium at start of filter run. Simple relationships between initial concn. of suspended matter, characteristics of sand grains, veloc. of flow, and characteristics of water are developed. These theoretical relationships are verified by comparison with actual exptl. data obtained by others.—*PHEA*

A Comparison Between Slow and Rapid Filtration. P. GUINVARC'H & P. BLANCHARD. Tech. Sanit. et Munic. (Paris), 51: 89 ('56). Authors define slow and rapid filtration and consider factors affecting rate of filtration, types of filters which may be used and need for disinfection of water after filtration. River waters are considered to be of 2 types: those of pH 7.5–8.5, which are usually colorless, have high alky. and contain little org. matter, and those of pH 5.5–7.5 which may be colored, and contain org. material and inorg. material in colloidal form. Filtrability of each type of water is discussed. Stds. to which treated water should conform are listed. Filtration of river waters on sand filters has been studied and tables are given of results of expts. to det. the effect on eff. of filters of: temp. of raw water; grain size of sand; depth of filter bed; rate of filtration; no. of times water is filtered. Authors describe, with reference to water works in Fr., rates of filtration and filter media used, prelim. treatment of water before filtration, and treatment after filtration. Eff. of rapid and slow sand filters in removal of suspended and colloidal matter, color, tastes, odors, org. matter, coliform bacteria, and algae, are compared and results of comparative expts. given in tables. Discussed are problems encountered in prelim. treatment of water, treatment after filtration, and operation of filters; need for trained operators; and costs of 2 methods of filtration.—*WPA*

Study of the Variations in Porosity of a Filter Medium Composed of a Regular Column of Identical Particles. R. COLAS. L'Eau (Paris), 42:283 ('55). In theoretical treatment of filter medium composed of identical spheres, in stable and unstable equil., eq. are evolved which lead to expressions for max. and min. porosities of medium. Theory is based on parallelepipeds formed between

(Continued on page 64 P&R)

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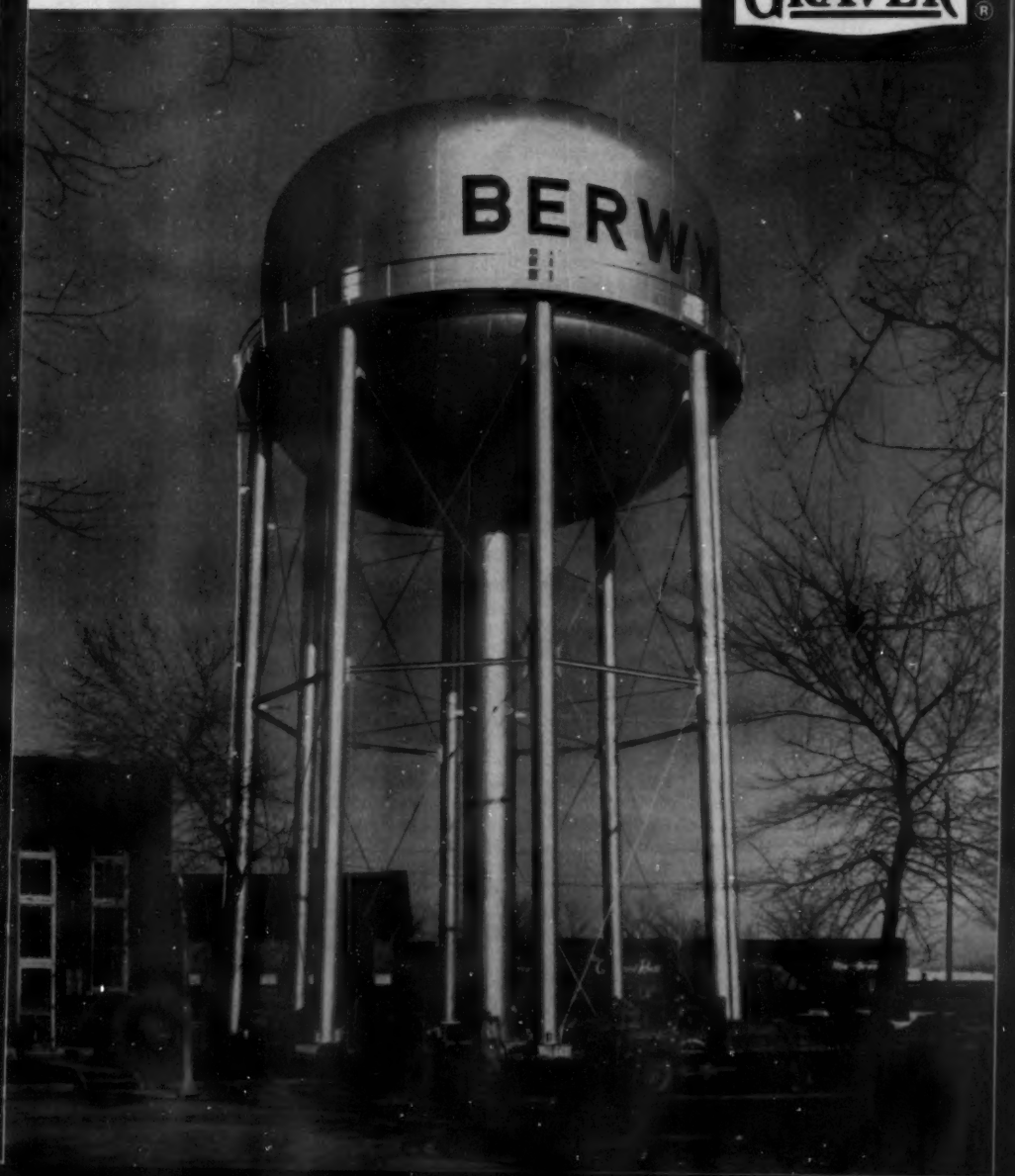


(*Continued from page 62 P&R*)

centers of 8 adjacent particles in medium. Similar formulae can be derived for particles of different shape.—*WPA*

Media Characteristics in Water Filtration. G. Ghosh. Proc. ASCE, **84**:SA1, Paper No. 1533 ('58). Study has been made on effects of veloc., depth, media size, and initial turbidity on head loss and eff. in water filtration. When chem. coagulants are not used, and with coarse grains in media, removal of turbidity is well distributed throughout filter bed.—*CA*

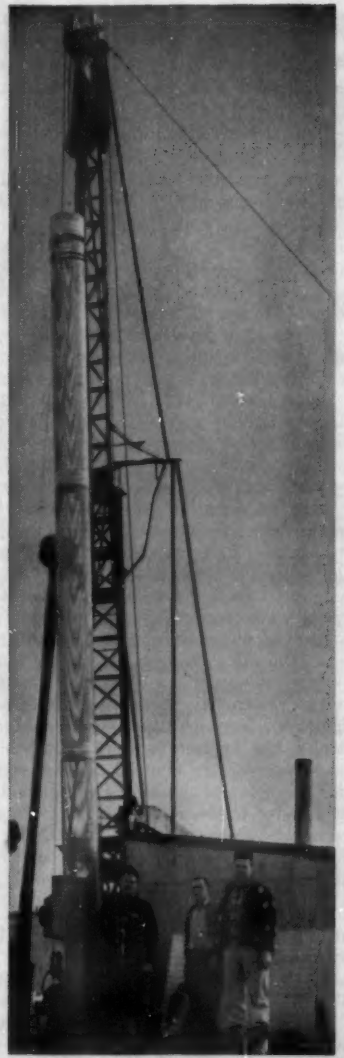
The Effect of Periodicity of Dosing on the Amount of Film and Numbers of Insects and Worms in Alternating Double Filters at Minworth, Birmingham. H. A. Hawkes. Inst. Sewage Purif., J. Proc. (Br.), Part I, 40 ('55). Periodicity of dosing has marked effect on accumulation of film and on grazing fauna. Reduction in film in upper layers of filter, caused by increasing time between doses of sewage, may be attributed partly to starvation and partly to increased scouring action of high instantaneous rate of application of sewage to surface. Increasing period between doses has beneficial effect on condition of filters and, up to certain time, on purif. eff. Also, by reducing amt. of film, and thereby maintg. fly pop. at low level, possibility of nuisance from adult flies is very considerably reduced. —*PHEA*

High-Rate Filter Cures Pollution; Wins Thanks of Downstream Farmers. R. H. Young. Wastes Eng., 27:489 ('56). Septic tank designed for 1,500 persons served Crystal Springs, Miss., with pop. of 4,000. Riparian owners below town, along stream receiving septic tank effluent, brought legal action against Crystal Springs. This resulted in new sewage treatment plant being designed for a pop. of 6,000, which was built and put into operation on Nov. 30, 1955. Plant consisted of Raw Sewage Pumping Station; Primary Clarification; High-Rate Filtration; Final Clarification; Effluent Chlorination; Sludge Digestion; Sludge Drying. Design factors employed are listed in article. Shortly after new plant was put into operation, Crystal Springs received plaudits from those who formerly voiced complaints.—*PHEA*

Membrane Filter Method Applied to Activated-Sludge Suspended-Solids Determinations. R. S. Engelbrecht & R. E. McKinney. Sewage and Ind. Wastes, **28**:1321 ('56). Membrane filter method for detg. activated-sludge, mixed-liquor, suspended-solids is described and evaluated. Errors and technical difficulties of Gooch crucible method (*Standard Methods*, 1955, 10th ed.), the centrifuge, sp. gr., and Al dish method (Smith, CA, **29**: 1914), and filter paper method (Fraschina, CA, **43**: 8582d) are discussed and compared with described method. Procedure is relatively simple to follow and is more precise than reported methods. Std. deviations with activated-sludge suspended-solids, ranging from 276 to 4,746 mg, were less than 1.6%. Data are presented to show that procedure can be adapted to suspended-solids detn. in raw sewage. Disadvantages associated with method are mentioned, particularly cost of filter membranes which limits procedure to detn. for research purposes.—*CA*

Use of Membrane-Filter Technique for Testing Water Supplies in the Field. M. C. Hope & A. H. Neill. Public Health Repts. (U.S.), 71:1093 ('56). 86% agreement in results obtained by membrane-filter technique and std. diln.-tube test on same samples is considered satisfactory. Elimn. of mechanical difficulties experienced would undoubtedly further increase the agreement. Results of membrane-filter tests were known in less than 1 day and were directly applicable to evaluation of individual water supplies which had been surveyed during course of studies. When samples were mailed to central labs., results of std. diln.-tube method could not be obtained in less than 7–10 days. Samples collected from surface-water supplies during early spring runoff generally contained high turbidities which were difficult to analyze by membrane-filter method. Satisfactory results were obtained when portable testing kit was set up in central shelter where samples were brought for anal. Exposure to open-air conditions affects operation of kit if anal. is made at sampling site. Operation of kit is simple and rapid; however, specialized training and familiarity with equip. are necessary to obtain results which can be properly evaluated.—*CA*

(*Continued on page 66 P&R*)



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(*Continued from page 64 P&R*)

The Effect of Periodicity of Dosing on the Efficiency of Percolating Filters. T. G. TOMLINSON. Inst. Sewage Purif., J. Proc., Part 1, 40 ('55). Expts. described show that accumulation of film in circular filters can be reduced by adjusting speed of distributors. Improvement in general condition of filters brought about in this way probably accounts for increased eff. which is particularly marked during winter. Increasing period beyond certain value tends to cause decrease in eff. Constr. of rectangular filters with distributors travelling at relatively low speeds and periodic dosing of circular filters from siphons achieve same object, but comparison with circular filters with continuous rapidly rotating distributors treating same type of sewage and at same rate is seldom possible. This may account for neglect of this aspect of biol. filtration until LUMB and BARNES read their paper in '48. Optimum period of dosing will vary within certain limits with filter, rate of treatment, and method of operation. In Minworth expts. optimum speed of 4-armed distributors was in region of 1 revolution in 15–30 min. Since radial distance between most of jets of adjacent arms was only 3–6 in., dosing period may be considered to be about ¼ time of revolution, or say 4–8 min for high proportion of filter surface at higher rates when flow was more evenly distributed between 4 arms. Although Coventry expts. were not carried on for long enough to show any marked differences in performance between filters operated with dosing periods varying from ¼ to 12 min, consideration of the expts. as whole led to conclusion that most reliable results were obtained with 12-min period.—*PHEA*

An Analysis of Sand Filtration. W. A. HALL. Proc. ASCE, 83:SA3, Paper No. 1276 ('57). Although sand filtration has long been used as means of removing most of suspended matter and bacteria from water, nature of process by which solids are removed by filter has not been clearly defined. If satisfactory theory of mechanics of filtration could be developed, it should be possible to improve design of sand filters, and author, therefore, has attempted to develop relation for distr. of sediment in filter in terms of space-time coordinates and phys. properties of components of system.—*WPA*

Humus Tank Performance, Micro-Straining, and Sand Filtration. N. P. NICOLLE. Inst. Sewage Purif., J. Proc., Part I, 19 ('55). Following conclusions were drawn: For humus tank detention periods of 3 hr or less on avg. flow, percentage removal of humus is approx. 50% and suspended solids are 25–35 ppm in tank effluent. With detention periods of 4–6 hr, increase in percentage removal of suspended solids to approx. 75% can be expected, and suspended solids will be below 20 ppm. There seems to be hardly any difference in performance between Dortmund tanks, clarifiers, and clariflocculators when operating on equal detention periods. As regards constr. costs, figures available indicate relatively small differences only for various types of tanks with similar capacs. Tests with micro-straining have not been very satisfactory. There has been trouble with breaking of straining fabric and slime growths on fabric. Costwise and performancewise, it appears better to use humus tanks where high suspended matter is encountered. Sand filters were installed to prepare water for cooling purposes. Various types of filters were used for exptl. purposes. One filter using carborundum blocks in place of gravel is giving satisfactory service. There has been no trouble with plugging of blocks. It appears that micro-straining can replace sand filters when influent contains less than 20 ppm suspended solids. A suggested plan was treatment on a biol. filter followed by 4–6 hr settling in humus tank followed by micro-straining for effluents to be used as cooling waters.—*PHEA*

Continuous Sampling of Trickling Filter Populations. I. Procedures. W. B. COOKE. Sewage and Ind. Wastes, 30:21 ('58). Modified technique of TOMLINSON (CA, 37, 2498) was employed by author in this investigation. Sampling collection procedures, sample transportation, lab. methods employed, recovery of dried growth, plating procedure, counting, and details of objectives are presented. Location under study was sewage-treatment plant of city of Dayton, Ohio. Flow diagram of plant illustrates equip. and operation. Process was described in light of results obtained during the investigation.—*CA*

(*Continued on page 68 P&R*)

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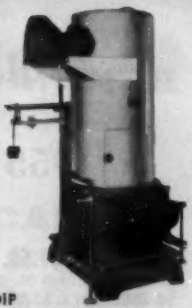
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(*Continued from page 66 P&R*)

Expansion of the Little Rock Filter Plant. D. N. Dodd. Southwest Water Works J., 39:5:48 ('57). It has become necessary to expand water filtration plant at Little Rock, Ark. It was decided to increase capac. of plant from 23 to 48 mgd by increasing capac. of 12 filters from 2 to 3.5 mgd and of 14 older filters from 0.5 to 2 mgd. Raw water is obtained from L. Winona. Treatment comprises coagulation with alum, disinfection with ammonia and chlorine, sedimentation, rapid sand filtration, adjustment of pH value with lime, and fluoridation. 4 new filters with capacs. of 16 mgd were installed. Description of these filters and of modifications made to existing plant is given (see also *WPA*, 30:2067, '57).—*WPA*

The Development of Biological Filtration. H. H. Stanbridge. Wtr. & Waste Treat. J., 6:409, 413, 417 ('57). This is continuation of series of articles on development of biol. filtration. Discussions of high-rate single-filtration are completed and early experiences with double filtration are described.—*PHEA*

The Development of Biological Filtration. H. H. Stanbridge. Wtr. & Waste Treat. J., 6:465, 469, 473 ('57). This is continuation of discussions of different methods of applying biol. filtration. Parts on double filtration are completed and discussion is started on alternating double filtration.—*PHEA*

Precious Water. Modern Sanitation, 7:9: 17 ('55). Trans-World Airlines have a 70-gal circulating water system on their Super-G Constellations which replaces more costly and weighty "thermos-jug" system. Water is chlorinated by means of dissolving 1 25-grain Taclor tablet (contg. calcium hypochlorite) in water at each refill. Activated carbon charcoal filter at drinking water outlets removes tastes and odors, including those caused by high chlorine concn., and turbidity and amoebic cysts are also removed by filtration. Continual circulation to prevent freezing is achieved by pump system. At regular maintenance check system is drained and refilled with water and sodium hypochlorite, which is circulated for at least 2 hr. This is emptied and regular service resumed. Light-wt. metals used in aircraft

(*Continued on page 70 P&R*)

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(*Continued from page 68 P&R*)

plumbing may corrode easily with high chlorine concn., and if so may have to be replaced by stainless steel or brass.—*WPA*

How to Prevent Clogged Filter Distributors and Filter Stone. L. W. Van Kleeck. Wastes Eng., **28**:25 ('57). This article is detailed discussion which will serve as guide for operators from starting of new filters to operating and maint. problems of filter. It is pointed out that stone dust can cause settling-tank sludge hopper clogging. Removal by flushing with fire hose, or backflooding, if possible, is discussed before putting filter in operation. Maint. of siphon chambers is outlined and should be helpful in obtaining good performance from this unit. It is suggested using small screen at entrance of siphon chamber to collect floating particles that come from primary. To secure proper distr. fixed spray nozzles or filter arms must be kept clean. Rotary distributors should be leveled and painted at least once per yr with special type of moisture-penetrating paint. Control of ponding is detailed and various causes are discussed, and remedies for ponding depending on particular problem.—*PHEA*

Graphite Ore as a Filter Material. L. Hirsch & E. F. Gloyna. Southwest Water Works J., **38**:3:15 ('56). Crushed graphite ore of 0.40-mm effective size and 1.60 uniformity coeff. is suitable filter material and surpasses sand and anthra in providing turbidity-free effluent. It is easily backwashed, and clean bed can be obtained in comparatively short time. Less H_2O is required to backwash filter than for sand filter. Radioactive $Fe^{55, 59}$ isotopes as $FeCl_3$ was effectively used to det. deg. of floc penetration in filter bed.—*CA*

Chicago Builds Biggest Filtration Plant. G. S. Salter. Eng. News-Record, **158**:26, 49–50, 54, 61 ('57). Chicago Central Dist. water filtration plant, capac. 960 mgd, is under constr. and is scheduled to be completed by '61. Treatment plant will serve pop. of 3,000,000, who at present receive L. Michigan water treated only by chlorination. Planning of plant, choice of site, and present progress in constr. are discussed.—*WPA*

Rapid Gravity Filters Installed at Madras Water Works. Surveyor (London), **117**: 77 ('58). After brief description of developments in water supply system to Madras City (India) since 1843, installation of rapid gravity mechanical filters of 10 mgd capac. at Kilpauk water works, which supplies pop. of 1,500,000, is described in detail. Red Hills lake water from which supply is drawn contains high percentage of dissolved org. matter which, owing to decompn. and reduction, had imparted distinct odor of hydrogen sulfide to water filtered through slow sand filters; rapid gravity mechanical filters were found to be most effective means of elimg. this trouble. Raw water passes through stilling chamber; is treated with 1.5–3 grains of aluminium sulfate/gal and with 0.3 ppm copper sulfate to control algae; settled in clariflocculator tanks; and filtered. Main features of mechanical filters are that rate of filtration is about 40 times that of slow sand filters; washing is carried out mechanically using compressed air and water under pressure instead of manually; and cleaning is more frequent. 10-mgd output is mixed with 25 mgd from slow sand filters which it is also proposed to replace with a 30-mgd rapid mechanical filter. Problem of finding addnl. sources of water supply not dependent on NE monsoon is very urgent. Proposals include: use of water from Krishna and Godavari rivers; erection of falling shutters over Tamarapakkam Anicut to divert more flood water from Kortalayar R. for storage; use of floodwaters from Arniyar R., which involves finding method of conveying water from recently constructed res.; and laying pipeline to connect Satyamurthi Sagar Res. at Poondi to Red Hills L., to minimize loss of water by evapn. and percolation in transit.—*WPA*

Test of Anticipation of the Activity of an Industrial Filter and of Estimation of the Biological Activity of a Water. E. Leclerc; P. Beaujean; & F. Devlaminck. Bull. centre belge d'etude et document. eaux (Liege), **36**:121 ('57). Industrial filter in use is described, results of its activity are given, and plankton obtained are illustrated and listed according to Kolkwitz classification. Relation was found between materials retained by filter, deg. of purity of water in stream or canal, and 5-day BOD studied

(*Continued on page 72 P&R*)

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(*Continued from page 70 P&R*)

both qualitatively and quantitatively. Relation was established between Beaudrey indices and activity of industrial filter, nature of suspended matter, and 5-day BOD.—*PHEA*

Use of the Membrane Filter for Potable Water in the Air Force. T. C. JONES. US Armed Forces Med. J., 8:1495 ('57). Following discussion of field methods of producing potable water and need for rapid, reliable means of checking adequacy of these methods, experience of AF with new portable membrane filter lab. kit weighing from 26 to 30 lb complete is presented. Filter kit and technique of using it are briefly described. Comparisons are made between membrane filter and standard M.P.N. methods of bact. anal. in examg. sea water, showing 87% agreement in results and considerable savings in time and cost by using membrane filter. 9 significant advantages and 5 disadvantages of using membrane filter instead of M.P.N. methods are given, indicating high desirability of adopting membrane filter kit as field water-testing device by armed forces. 5 other possible uses, in addn. to water testing, for membrane filter (air poln. studies, size detn. of silica particles, *et al.*) are mentioned, indicating its versatility and adaptability.—*PHEA*

Use of Membrane Filters in Sanitary-Bacteriological Analyses. O. BENDOVA. Kvasny Prumysl, 1:106 ('55). Results are reported of detn. of *Escherichia coli* in water by means of membrane filters and FICKER-PARTIS method. In F.-P. method filter can be kept as document of anal., but use of membrane filters is simpler, quicker, and essentially more precise.—*CA*

The Use of Endo Medium in Conjunction with Green-Netting Membrane Filters for Tracing Coliform Bacteria in Water. J. PAPAVASSILIOU. Zentr. Bakteriol. Parasitenk., Abt. I Orig. (Stuttgart), 170:6/7: 538 ('58). Membrane filter method for isolation and enumeration of coliform organisms in water has been improved by using new combinations of Endo medium and lattice-membrane filters, delivered from mfrs. ready for use in sterilized pkgs. Although Endo medium has certain disadvantages, these are largely elimd. by carrying out 2 filtrations and incubating 1 membrane at 37°C and other at 44°C.—*BH*

The Dutch Immedium Filter. ANON. Water and Water Eng., 62:217 ('58). In this filter upward flow is used. Liquid to be filtered is introduced into bottom loose-grained filter medium instead of top fine-grained sand. Outlet drain consists of hollow sphere which is made of permeable material. This sphere is located in fine sand near top of filter.—*CA*

Some Percolating Filter Experiments at Cheltenham. J. D. PEACH. Inst. Sewage Purif., J. Proc. (Br.), 2:111 ('57). 2-stage filtration gave better results than either alternating double filtration or filtration with recirculation of settled effluent. Where such system could be operated without pumping, it would show considerable saving in both capital and operational costs. Periodicity of dosing of filters that are required to operate at high dosage rates plays vital part in prevention of ponding.—*PHEA*

Experiences in Use of the Tower Percolating Filter. SCHULZ. Stadtehygiene, 6: 67 ('55). Report of paper presented at conf. on water chemistry in Berlin in Jan. '55. Tower percolating filter has greater capac. than normal high-rate filter. Constr. of filter, which operates with forced aeration, is described. Experiences with exptl. plant, 1 m in diam., 8 m high, and arranged in 4 sections are described. It was operated with artificial aeration at load of 15 cu m of sewage/cu m of medium per day, or 3,100–3,900 g of BOD/cu m/day. Reduction of 71% in BOD was obtained and effluent contained 2.8 mg of oxygen/l. Action of different stages was examd. and was found to be reducing in 1st 2 stages and thereafter oxidizing. In expts. without artificial aeration, load of 3,000–3,500 g of BOD/day/cu m was applied; 91% reduction in BOD was obtained. Effluent contained 6 mg of oxygen/l and had BOD of 22 mg/l. In last stage nitrate was present, 83% of org. nitrogen being decomposed. This rate of loading is about 4½ times normal load. In design of plant ratio of diam. to ht. of 1:6 is recommended. Data are given on use of this plant for treatment of sewage contg. phenolic disinfectants from sanatoria, for prelim. treatment of slaughterhouse waste waters before activated-sludge treatment, and for waste waters contg. phenol or fatty acids. Further investigations are to be made on

(*Continued on page 74 P&R*)

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(*Continued from page 72 P&R*)

treatment of industrial waste waters and effect of addn. of substances contg. nitrogen and phosphorus. Experiences in practice are described.—*PHEA*

The New Installation of Rapid Filters of the Zurich Water Works. E. BOSSHARD. Aqua, 1:8 ('55). Water supplies for Zurich (Switz.) are obtained from spring, and underground stream, and by intake of water from L. Zurich. Owing to increased consumption it has been necessary to increase amt. of water taken from lake to 150,000 cu m, more than ½ total supply. This water, due to abundance of blue-green alga, *Oscillatoria rubescens* and to pptn. at beginning of summer of limestone crystals, is difficult to filter, and double filtration plant, previously giving satisfactory performance, was unable to deal with increased load. To overcome this difficulty rapid sand filters have been installed to treat ½ of lake water by rapid filtration, which after chlorination is mixed in storage res. with remainder of lake water from double-filtration process. Operation of modified plant is described.—*PHEA*

Mechanism of Rapid Sand Filtration. G. GHOSH. Water and Water Eng., 62:147 ('58). Literature review of filtration of water through sand beds. Also included are results of investigations on effects of phys. characteristics of mediums on filtration of turbid waters. Known turbid waters were passed through filtering mediums of different sizes. Sand offers less resistance to flow but absorbs more material than glass ballotini of same sieve size. Usual belief that first few in. of bed takes up major burden of filtration is not correct. While top 3 in. and top ¼ of bed do remove more than rest of bed, turbidity removal occurs throughout entire bed. Final turbidity of filtrate depends more on flow rate than size of filtering medium. Percentage removal of turbidity does not vary much with variations

(*Continued on page 76 P&R*)

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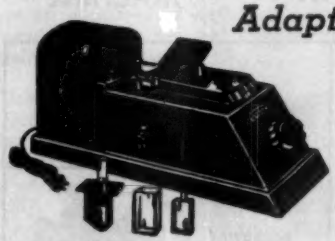

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(Continued from page 74 P&R)

in applied turbidity. It may, therefore, be more economical to process highly turbid waters directly by filtration rather than with pretreatment by sedimentation or coagulation.—*CA*

Sand Filters in the Clarification of Industrial Water. D. Goidea. Rev. chim. (Bucharest), 6:345 ('55). Several types of filter installations, their functioning, filtering materials, etc., are evaluated for different applications. General formulas are given. —*CA*

Study of the Filtrability of Water. E. Leclerc & P. Beaujean. L'Eau (Paris), 43:189 ('56). Filtrability is defined and necessity of considering filtrability of water when designing filters is emphasized. Methods of measuring filtrability are discussed, particularly methods of Suckling; of Beaudrey in Fr., which measures "colmatage index"; and of Boucher in Br., which measures "straining index." Relation between these 2 indices is considered. Investigations carried out to det. filtrability of natural waters from various Belg. rivers, from L. Gileppe, and from distr. system of Verviers (Belg.) are reported. Relation between "colmatage index" and time of operation of sand filter was studied on lab., semi-industrial, and industrial scales, industrial filter being that of Centrale Electrique des Awirs. No simple relation could be established between filtrability of water and content and nature of plankton organisms, either with lab. or commercial app. It is considered, however, that combined with other tests filtrability test can give information regarding poln. of surface waters. Work has been commenced on filtrability of waters which have been treated by coagulation.—*WPA*

Studies on BOD Loading of Trickling Filters Followed by Septic Tanks for Treatment of Human Excrements. I. Horasawa. Bull. Inst. Public Health (Tokyo), 6:14 ('57). Studies were carried out for purpose of obtaining fundamental data for design of adequate trickling filters followed to septic tanks which treat wastes from flush toilets. After brief consideration on factors affecting loading of filters, BOD loading to filters and proportional capacs. of filters based upon BOD loading were discussed. 1.) BOD loading to filters for ordinary household septic tanks was 6.693 g/head daily in avg. of samples and mean of pop. of sample was within 5.505–7.881 g of BOD/capita/day in 95% reliability. 2.) Avg. of BOD loading to filters including those of household, dept. stores, offices, factories, etc., in various dists. of Jap. was 6.097 g/head daily. 3.) Adequate capac. of filters based upon BOD loading, above mentioned, should be 112 L per capita for a private household septic tank and 102 L per capita for septic tanks treating wastes from flush toilets of factories, offices, restaurants, and others besides household ones.—*PHEA*

Is There a "Perfect" Trickling Filter Effluent? Corpus Christi Has Produced It and Now Sells It to Industry. S. L. Allison. Wastes Eng., 28:614 ('57). Records improvements over period of 20 yr to standard rate trickling filter plant whose effluent is purchased by refinery for process water. These yrs of striving for "perfect" trickling filter effluent have provided following information: high BOD reduction was obtained without ventilation of filters. Breaking of sewage into droplets increases DO but also increases odor production. Using thin sheet of flow from orifices will permit satisfactory results to 1,200 lb of BOD/acre-ft, but limited to 800 lb/acre-ft odors are to be prevented. Dosage rate must be adjusted for optimum results and flow maintd. for continuous dosage of filters. Advantages were found by chlorinating between filter and final clarifier. Improved primary clarifier eff. can be obtained by keeping accumulated sludge to min.—*PHEA*

Theoretical Performance of the Trickling Filtration Process. V. T. Stack Jr. Sewage and Ind. Wastes, 29:987 ('57). Author presents theoretical development of eq. which might be used in predicting and interpreting performance of trickling filter. Whereas certain variables must be evaluated experimentally, eq. should minimize pilot-scale studies. Expression has been in good agreement with actual data. Several appendices have been included illustrating math. development and application of eqs.—*PHEA*

(Continued on page 78 P&R)

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(*Continued from page 76 P&R*)

Continuous Sampling of Trickling Filter Populations. II. Populations. W. B. COOKE & A. HIRSCH. Sewage and Ind. Wastes, **30**:138 ('58). Use of glass slides has been found to be effective method of sampling pops. of microorganisms occurring on surface of trickling filters. Isolation techniques of this study permitted consideration of only fungi and algae but it is recognized that bacteria and protozoans contribute important segments to total pop. Mat on filter stones continuously receiving sewage appears to have definite structure, while that on stones receiving intermittent flow is more heterogeneous. Sloughing is related more to vigorous washing of excessive growth on filters under consideration than to development of septic layer at their base or to browsing or grazing of metazoal pop. During yr pop. of high-rate filter appears to be relatively uniform, although during winter adverse conditions may reduce algal pops. and in late winter and spring mos. *Fusarium aquaeductuum* may show marked increases. Standard-rate filter pops. are governed by intermittent flow of sewage and are much more erratic.—*PHEA*

Suspension of Secondary Treatment During Winter Months. T. J. PIECZONKA. Sewage and Ind. Wastes, **28**:1178 ('56). Factors which permitted shutdown of trickling filters in winter mos. without lowering stream qual. are described. During cold mos. there is sufficient DO and diluting water to compensate for lower effluent qual. Also, filters are less active and accumulate sludge which later overloads digesters when it sloughs off. Operating and maint. costs are reduced, but strict supervision is needed.—*PHEA*

FLUORIDATION

Adsorption of Fluorides by Alumina. R. A. CRESPI GHERZI; R. J. MANUELE; & I. DE AMEZOLA. Anales asoc. quim. arg. (Buenos Aires), **43**:238 ('55). Eff. of alumina for removal of fluoride from water is discussed. Chlorides and sulfates interfere with adsorption of fluoride.—*CA*

Current Status of Fluoridation in Canada. Munic. Util. Mag. (Can.), **95**:4:27, 53 ('57). Report is given of fluoridation of water supplies in various prov. of Can. up to end of '56. Method has been devised recently in US whereby naturally-occurring fluoride can be added to water; this should result in reduction of operating costs.—*WPA*

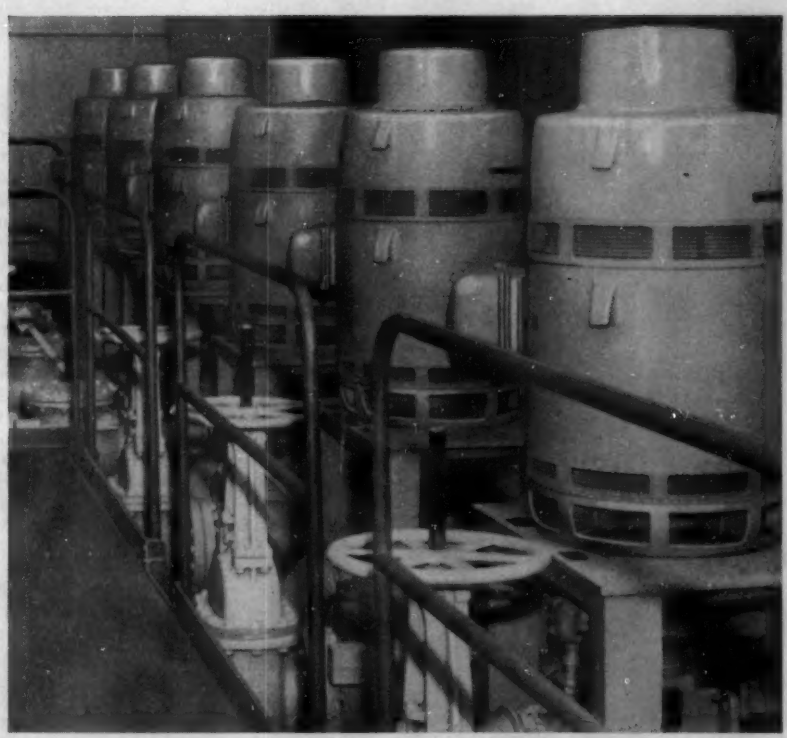
The Fluoride Enrichment of Drinking Water as a Measure of Control of Dental Caries. J. FLETCHER. Roy. Soc. Promotion Health J. (London), **77**:847 ('57). Author supports fluoridation as method of controlling dental caries. He outlines studies carried out by several workers concerned with relation between incidence of dental caries and fluoridation of water supplies and discusses briefly medical aspects of fluoridation.—*WPA*

The Trace Element Fluorine and Dental Caries. H. HORNUNG. Monatsschr. Kinderheilk. (Berlin), **105**:4 ('57). Dental caries is seldom found where water supply contains over 1 mg fluorine per l. Content of at least 2 mg per l. may cause slight mottling of enamel. Author has observed no harmful effect even with much higher concns. He contradicts many of arguments brought forward against fluoridation of water supplies. Other methods of intake of fluorine (tablets, etc.) cannot take place of its addition to water.—*WPA*

Determining Optimum Fluoride Concentrations. D. J. GALAGAN & J. R. VERMILLION. Public Health Rep. (US), **72**: 491 ('57). Method has been devised and formula suggested for detg. optimum fluoride concns. in water supplies. Method is based on fluid intake study described in *WPA* **30**: 11:2081 ('57) and takes into acct. variations in environmental temp.—*WPA*

Developments in Fluoridation. P. B. PEACOCK. Public Health, Johannesburg (S. Afr.), **20**:11:20, 28 ('57). Author reviews work carried out on incidence of dental caries in relation to fluoridation of water supplies; where fluoridation programs have been adopted, findings over no. of years have shown reduction of 50–60% in incidence of dental caries at comparable ages. Surveys into relative merits of various possible fluoridation vehicles have demonstrated that water is only reliable transport medium. Recent views on metabolism of fluorine in body and how it is taken up by teeth are

(*Continued on page 80 P&R*)



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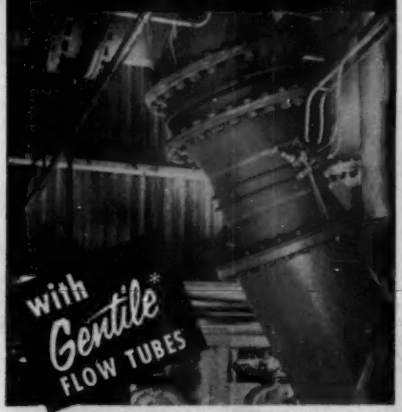

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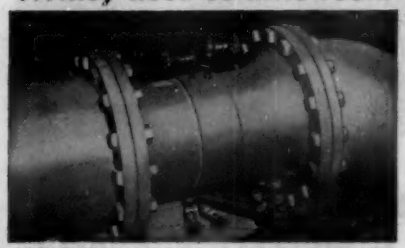

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(*Continued from page 78 P&R*)

outlined and various suggestions made as to how it protects teeth against caries. Suggestions are made for introduction of fluoridation scheme for S. Afr.; pilot scheme is already underway at Germiston. Different forms of fluoride which are used for fluoridation are discussed and possible advantages of adding smaller concns. of fluorine in summer mos. is dealt with briefly.—*WPA*

Fluoridation. A Study in Confusion of Function. G. Dobbs. Water and Water Eng. (London), **61**:201 ('57). Author presents arguments against practice of fluoridation of water supplies as means of controlling dental caries. He objects to fluoridation on grounds that it involves mass medication, that water contg. less than 1 ppm fluoride is not "deficient" in this element unless accepted purpose of water supply is to prevent dental caries in children, and that fluorine is toxic element which may produce chronic poisoning.—*WPA*

Water Fluoridation in Hastings. R. P. Fish. New Zealand Eng. (N.Z.), **12**:343 ('57). Experiences in fluoridation of water supply for Hastings, N.Z., are outlined. Water is obtained from artesian wells, and contains 0.15 ppm fluoride, so it is necessary to add 0.85 ppm fluoride to give desired concn. of 1.0 ppm. Originally, sodium silicofluoride was used, and applied as dry feed, but later it was decided to use more sol. sodium fluoride and apply it as soln. As water has hardness of 80 ppm calcium carbonate, some insol. calcium fluoride is pptd. when fluoride soln. is prepared, and this must be removed from mixing tank at intervals. Control of operation, precautions taken in handling fluoride, and costs of fluoridation are indicated briefly.—*WPA*

Fluoride Domestic Water and Periodontal Disease. A. L. Russell. Am. J. Public Health, **47**:688 ('57). In paper presented at an Am. Pub. Health Assn. Meeting, '56, author summarizes evidence obtained relating periodontal disease to use of fluoridated domestic water supplies. Relevant data collected during summer of '56 is based on examns. of nearly 20,000 persons, of both sexes, ranging in age from 7 to 78 yr. Most common method used for this type of study is to contrast pop. drinking fluoride-free water with other pops. using domestic wa-

(*Continued on page 82 P&R*)

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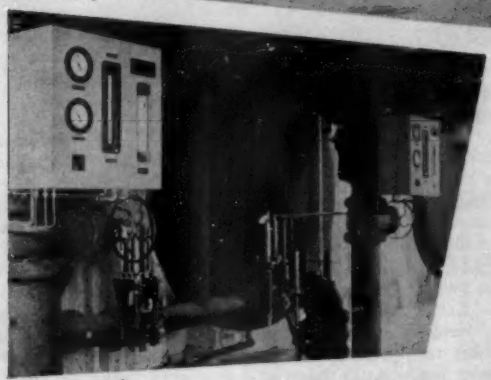

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(*Continued from page 80 P&R*)

ters of varying fluoride concn. Condition of periodontal tissues of residents of 3 communities, Newburg, N.Y., Colorado Springs, Colo., and Bartlett, Tex., where water supplies contain fluorine, was compared with that of residents of 3 comparable low or nonfluoride communities of Kingston, N.Y., Boulder, Colo., and Cameron, Tex., respectively. Domestic water supplies of fluoride communities carried about 1.0, 2.5, and 8.0 ppm fluoride respectively. Results of these studies are presented in tables and show that in each example, more favorable condition of periodontal tissues was observed in community with fluoridated water supply. Addnl. evidence on this subject has resulted from contrasting condition of natives in fluoride community with that of migrant persons who have used same water for shorter period of time. No adverse effect was apparent upon periodontal tissues of native children related to length of time they had consumed fluoride-bearing water.—*WPA*

The Fluoridation of Public Water Supplies. J. R. FORREST, ET AL. Roy. Soc. Promotion Health J. (London), **77**:344 ('57). In symposium on fluoridation of public water supplies, presented at the Health Cong. organized by Roy. Soc. Promotion Health in May '57, J. R. FORREST surveyed effect fluoridation has on incidence of dental caries (see WPA, **30**:8:1443 ('57)). W. ALCOCK reviewed effect of fluorine on public health and derived scale of toxicity. Large doses, taken orally, produced nausea, vomiting, or death; chronic fluoride poisoning results in abnormal bone development; but there is no evidence to show that concn. of 1 ppm fluorine in drinking water is injurious to public health. W. T. C. BERRY discussed action of fluorine on bone, kidney, and soft tissue, and its part in prevention of dental caries. J. LONGWELL considered chem. and technical aspects of fluoridation of water supplies (see WPA, **30**:8:1444 ('57)). In discussion J. H. C. CLARKE described condition of children's teeth in Kesteven division of Lincolnshire, where fluorine content of water supplies ranges from 0–4 ppm.—*WPA*

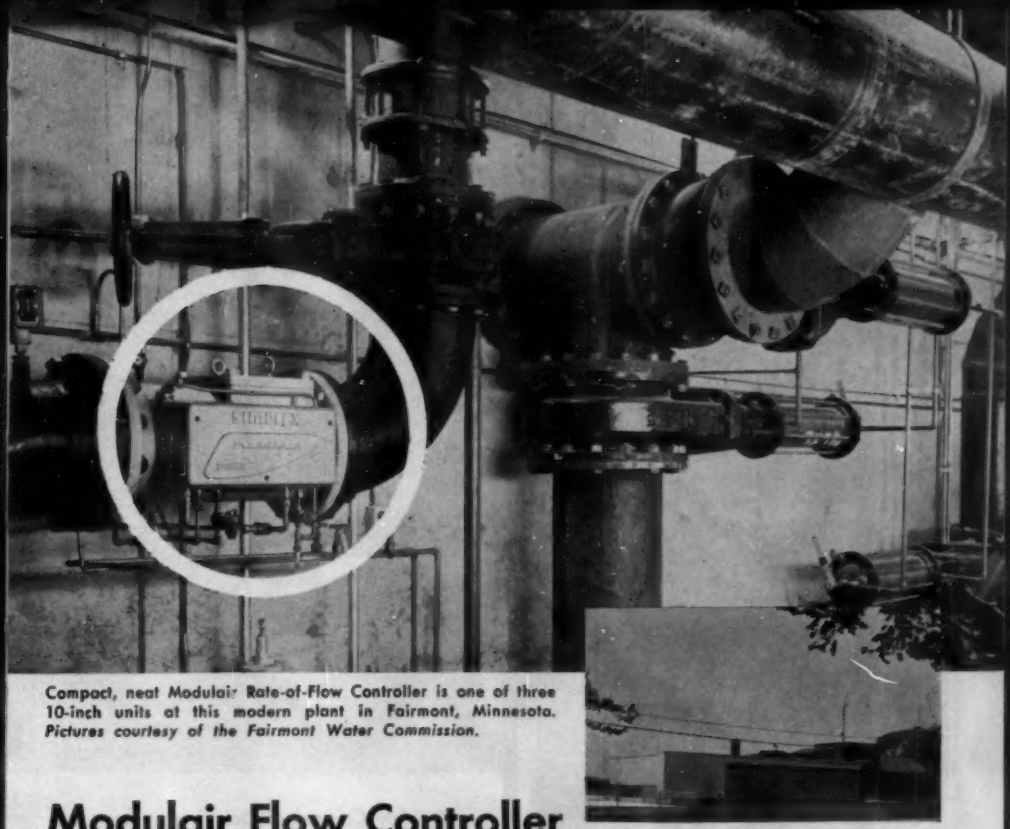
Fluoridation of Water Supplies. C. PARMA. Deut. Zahnarztebl. (Ger.), No. 22 ('56). Author considers general problem of addn. of fluorine to water supplies and importance for tooth formation of presence of other minerals. Action of fluorine on enamel and surface of teeth and on bone formation is discussed. Increase in amt. of magnesium in water increases anti-caries effect of fluorine. Statistics in US show that in dists. with added or natural optimum amts. of fluorine in water supply there is decrease in bone fractures, nephritis, and severity of diabetes. Author has observed in S. Bohemia that in dists. poor in fluorine, bone formation is delayed and fractures heal slowly. Other possible methods of administering fluorine should be considered as well as addn. to water supply. Author concludes that water supply should not only be bacteriologically and chemically satisfactory but should contain optimum amts. of all minerals of importance for body, including fluorine.—*WPA*

Fluorine Treatment of Water Supply. K. GEDICKE. Desinfekt. u. Gesundheitsw. (Ger.), **49**:40 ('57). Author gives figs. for prevalence of caries in different age groups and supports addn. of fluorine to water as preventive measure.—*WPA*

Water Fluoridation Is Effective, Safe and Practical, Say World Health Organization Experts. Public Health, Johannesburg (S. Afr.), **20**:12:39 ('57). World Health Org. comm. of experts, appointed to investigate water fluoridation, has concluded that it is effective, safe, and practicable method of preventing dental caries. Other methods of fluoridation which are being investigated include systematic admin. of fluorine in milk, table salt, and fluoride tablets, latter having shown some positive effects. Expts., however, have not lasted long enough to give any definite proof, but research on these alternative methods should be encouraged as they may become valuable in regions where water fluoridation is impossible.—*WPA*

Fluoridation and the Removal of Fluorides from Water. G. MONTEL. L'Eau (Paris.), **43**:77 ('56). Author discusses origin of fluorides in water supplies. He then goes on to describe chem. reactions which occur between dissolved fluorides and hydroxyapatite, monocalcium phosphate, and hydrated forms of tricalcium and bicalcium phosphate. Knowledge of these reactions is necessary when choosing most suitable compd. for removal of excess fluorides from water.—*WPA*

(*Continued on page 84 P&R*)



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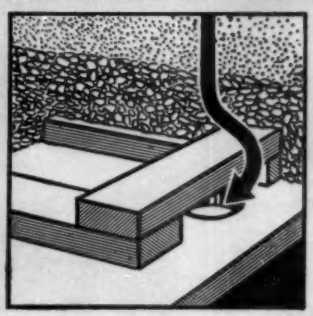

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(*Continued from page 82 P&R*)

Removal of Fluoride Ion From Water With Activated Alumina. E. A. SAVINELLI. Dissertation Abstr., 15:2405 ('55). Results of investigations are given to show effects of a number of variables on fluoride ion-exchange capac. of activated alumina regenerated with dilute solns. of filter alum, and these results are discussed. Method appears useful with water of high alky. due to carbonate hardness, but not with water contg. sodium or potassium bicarbonate.—*WPA*

Rate of Urinary Fluoride Output in Normal Adults. I. ZIPKIN & N. G. LEONE. Am. J. Public Health, 47:848 ('57). Authors describe expts. to det. hrly. rate of urinary fluoride output of normal adults. In control expts. fluid intake was 200 ml. of water contg. 1 ppm fluoride. In 2nd expt. "challenge" dose of 5 mg of fluoride in 200 ml of water was administered. Results are shown in tables. It was found that fluoride was elimd. most rapidly during 1st hr after dose. Rate then dropped until after 8 hr it approached rate observed during control expts.—*WPA*

Fluoride Content of Drinking Water. W. FRIESE. Pharm. Zentralhalle (Dresden), 94: 337 ('55). Review of fluoride content of natural waters of Europe.—*CA*

The Method of Determination of Fluorides in Water and Biological Material. H. MOMMIK. Schweiz. Mschr. Zahnheilk., 65:674 ('55). For detn. of fluoride in water, author recommends method proposed by Am. Public Health Assoc. ('46) and describes removal of interfering effects of bicarbonate and aluminium. In detn. of fluoride in biol. material error may arise during ashing in elec. muffle furnaces owing to presence in lining of silicates contg. fluoride.—*WPA*

Orienting Experiments on the Influence of Soils on the Fluoride Content of Waters. W. JAHN-DEESBACH. Wasserwirtsch.-Wassertech. (Berlin), 7:384 ('57). Many published data on fluoride content of waters from different sources are in error, older data suffering from poor anal. methods and more recent data from procedural errors. Direct anal. for fluoride content often gives much too high results; in addn. to F ion, SO_4 or Cl ions, for example, bind Th and

(*Continued on page 86 P&R*)

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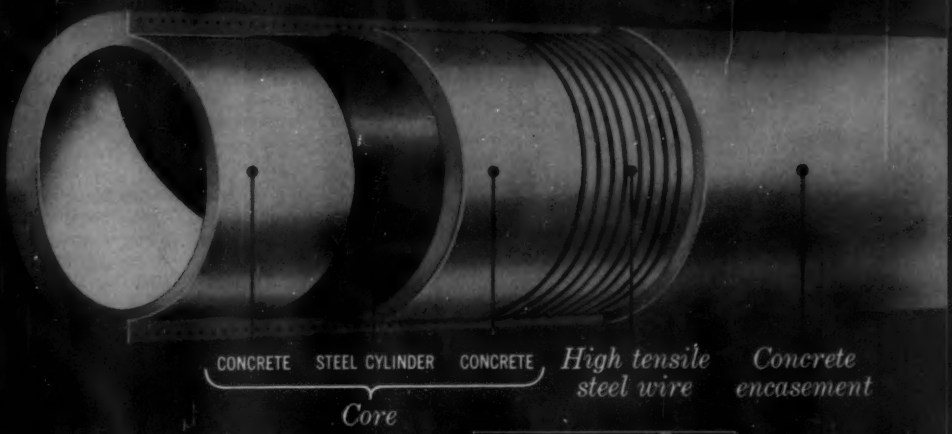

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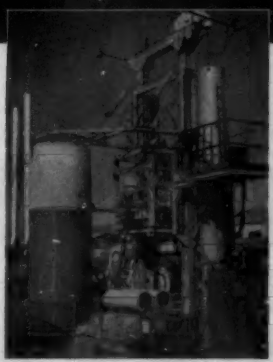

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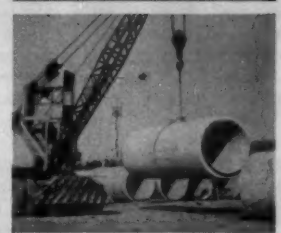

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(*Continued from page 84 P&R*)

Zr. Best procedure calls for evapn. of sample to near-dryness, with dropwise addn. of 0.1*N* NaOH, followed by distn. at 130°F in 60% $HClO_4$ soln. contg. Ag_2SO_4; interfering ions are removed by this method. Another reason for wide variation in published data on water anal. is natural difference in waters coming from different parts of geological formation. Phys. nature of soil at that point, its chem. compn., and length of time water has been in contact with it, etc., are all factors of importance. Tests on shell limestone, sandstone, and Silurian clay slate give fluoride contents of 0.40 and 0.45 mg/l in doubly distd. water percolated through upper layers of colored sandstone and middle layers of shell limestone and unmeasurably low F contents for other layers. Results also indicate that F bound to Ca, Na, etc., is more easily given up than F contained in micaceous soil or other mineral-bearing soils; presence of phosphate and carbonate is also important.—*CA*

Criteria to Consider When Supplementing Fluoride-Bearing Water. D. F. STRIFFLER. Am. J. Public Health, **48**:29 ('58). Results of observations on relation between avg. no. of DMF (decayed, missing, or filled) teeth and concn. of fluoride ion in water supplies, made on 12–14-yr-old residents of 36 cities in US, are tabulated, together with data previously obtained by DEAN from further 21 cities. Curves based on these data are presented for use in estg. reduction in rate of caries attack which can be expected after enrichment of fluoride-bearing water to optimal level. Advisability of supplementation should be considered in relation to following criteria: anticipated reduction in rate of caries attack, in dental care costs, and in toothaches; costs (capital outlay and operating costs); attitude of governing body toward fluoridation; and local factors such as climate, no. of children, qualifications of water works staff, and economic status of community.—*WPA*

Fluoridation of Public Water Supplies and Its Relation to Musculoskeletal Diseases. C. L. STEINBERG ET AL. New Engl. J. Med., **258**:7 ('58). Fluoride concn. in bones has been found to increase logarithmically with age. When fluoridated water at 1 ppm is ingested concn. of fluoride in bones increases, but level never reaches that previously reported for cases of excessive fluoride exposures. Same would be true even if none of fluoride were excreted. Anal. of bones from patients suffering from various rheumatic disorders were analyzed and those residing in fluoridated areas showed higher fluoride concns. than those residing in nonfluoridated areas. However, in no case was concn. excessively high, and no correlation between various forms of arthritis and ingested fluoridated water was evident.—*PHEA*

Symposium on the Fluoridation of Public Water Supplies. (a) The Dental Aspect. J. R. FORREST. **(b) Medical and Public Health Aspects.** W. ALCOCK. **(c) Some Physiological and Clinical Aspects of Fluoridation.** W. T. C. BERRY. **(d) Chemical and Technical Aspects.** J. LONGWELL. **Discussion.** Roy. Soc. Promotion Health J. (London), **77**:7:344 ('57). S. R. FORREST gives acct. of principal fluoridation studies in US, Can., and UK. She includes details of survey carried out in areas in Essex and Surrey (Br.) where fluoride content of water is negligible, and in 4 fluoride areas (Slough, 0.9 ppm F [fluoride concn.]; Harwich, 2.0 ppm F; Burnham-on-Crouch, 3.5 ppm F; and W. Mersea, 5.8 ppm F). Incidence and severity of enamel mottling were found to be directly related to fluoride content of water; with 5.8 ppm F, 95% of children were affected but mottling became progressively less with lower F, and at level of 0.9 ppm F it was negligible. W. ALCOCK deals with acute and chronic fluorine poisoning, and suggests following "scale of toxicity":

Acute fatal poisoning	2,500 mg (approx.)
Acute nonfatal symptoms	125 mg
Chronic severe fluoride poisoning	20 mg daily
Dental mottling but no known systemic effects	>2 mg daily

He discusses various pathological conditions, *e.g.*, kidney disease, for which fluorine ingestion has been blamed, and concludes that consumption of fluoridated water will in no way affect adversely general health of community ingesting it. Considerable part of W. T. C. BERRY's contribution deals with

(*Continued on page 88 P&R*)

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(*Continued from page 86 P&R*)

absorption of fluorine by bone. He also discusses effect of fluorine on kidneys, and he refers to possibility of fluorine allergy. He mentions point, noted also by J. R. FORREST, which is that teeth in fluoride area appear to be of unusually good structure, with few of developmental defects which are seen in so many children in nonfluoride areas. W. T. C. BERRY believes it to be probable that fluorine will turn out to be essential nutrient. J. LONGWELL refers to various fluoride salts used in water fluoridation, and describes equip. and methods of control devised for that purpose. At present water supply of 4 areas in Br. is being fluoridated, and J. LONGWELL gives cost:

Area	*Total Cost—pence/head/yr*
Anglesey (half island)	4.7
Andover	7.4
Watford	3.4
Kilmarnock	6.2

His contribution contains considerable amt. of information regarding intake in Br. of fluorine from various articles of food and drink.—*BH*

WELLS AND GROUND WATER

The Geology and Ground-Water Resources of Marengo County, Alabama. H. SUTCLIFFE JR. & J. G. NEWTON. Geol. Survey Ala., Inform. Serv. No. 4:1 ('57). Chem. anals. are given of waters from 84 wells. Most are not hard, but are high in bicarbonate (500–700 ppm) and many contain 1.6–4.4 ppm F. Some are very high in Cl (up to 5,690 ppm).—*CA*

The Geology and Ground-Water Resources of Wilcox County, Alabama. P. E. LAMOREAX; L. D. TOULMIN; & H. SUTCLIFFE JR. Geol. Survey Ala., Inform. Serv. No. 8:1 ('57). Chem. anals. are given of 48 waters, mostly soft. 19 of these samples contained 1.0–4.0 ppm F.—*CA*

Ground-Water Resources of Parts of Lonoke, Prairie, and White Counties, Arkansas. H. B. COUNTS. Ark. Geol. Conserv. Comm., Water Resources Circ. No. 5:1 ('57). This includes chem. anals. of 102 waters, mostly of Ca bicarbonate type. Waters in 1 area were very high in NaCl.—*CA*

Geology and Ground-Water Resources of Highlands County, Florida. E. W. BISHOP. Fla. Geol. Survey, Rept. Invest. No. 15:1 ('56). Chem. anals. are given of 36 water samples.—*CA*

Hydrological Preparations for the New Ground-Water Works of the Town of Dessau. G. THIEM. Reprint from Wasserwirtsch.-Wassertech. (Berlin), No. 4 ('55). After brief acct. of development of research into behavior and properties of ground water author describes investigations made in connection with new supply of ground water for town of Dessau (E. Ger.). Works are 10 km (6.2 mi) S. of Dessau. Hydrology of dist. and amt. and qual. of ground water are discussed.—*WPA*

Ground Water in the Molasse of South Germany and in Its Karst Marly Substratum. K. LEMCKE & W. TUNN. Bull. Ver. schweiz. Petrol.-Geologen u.-Ing. (Switz.), 23:64:35 ('56). Anals. of 7 waters show existence of zone high in NaCl and $NaHCO_3$.—*CA*

Quaternary Geology and Ground-Water Resources of Kansas River Valley Between Bonner Springs and Lawrence, Kansas. A. E. DUFFORD. State Geol. Survey Kan., Bull. 130:1 ('58). Chem. anals. of 19 waters are given. They are hard to moderately hard Ca bicarbonate waters contg. 0.1–0.4 ppm F.—*CA*

Ground-Water Resources of the Ladder Creek Area in Kansas. E. BRADLEY; C. R. JOHNSON; & R. A. KRIEGER. State Geol. Survey Kan., Bull. No. 126:1 ('57). Chem. anals. of 32 waters show them to be moderately hard calcium bicarbonate waters.—*CA*

Methaemoglobinaemia of Infants Caused by Well Water Containing Nitrate. F. W. WEDEMEYER. Arch. Kinderheilk. (Stuttgart), 152:267 ('56). Author describes 3 cases of methaemoglobinaemia in infants fed on milk powder dild. with well water. Shortly after occurrence of disease well water was found to contain up to 40 mg of nitrate/l. At later date highest content found was 3.75 mg. Nitrate content was thus subject to considerable variation. Author discusses other causes of methaemoglobinaemia.—*WPA*

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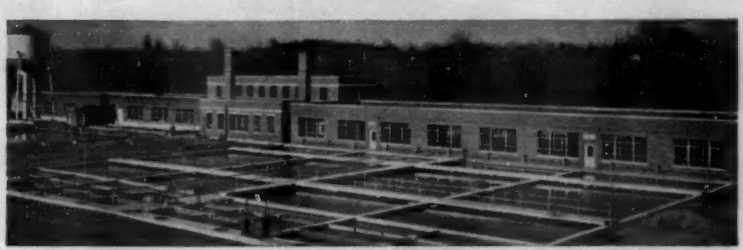

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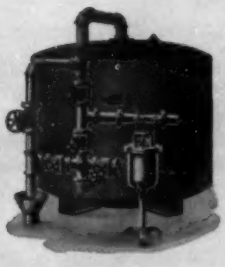

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Correspondence

Safety, First Cover

To the Editor:

Reading some back issues of the JOURNAL, a former safety engineer notes the picture on the March 1958 cover with awe. Not only is the untied workman standing on a scaffold that has holes in it and lacks a guardrail, but he is holding above his shoulders a live reaction motor of a sort.

It is suggested that the Association Safety Coordinator review pictures for safe practices before releasing them, lest we be accused of fostering accident prevention with tongue in cheek.

KENNETH A. DAY

Detroit, Mich.
Oct. 6, 1958

So we like suspense. So it ain't safe to print it. So we get nothing but complaints (see also p. 84 P&R of the April and May issues). So we've ditched this month's definitely dangerous cover girl in favor of the only obviously safe man we could find. Happy, Day?—ED.

Water Law

To the Editor:

In spite of the great respect and admiration I have for Abel Wolman, I must disagree most strongly with his view that, although a water statute ought to set forth the elementary principles of allocation, the statute should "not spell out their priorities. The administrative state agency, whether good or bad, must do that" ("A Fresh Approach to Water Law," October 1958 issue, p. 1283).

While I do not presume to be able to forecast how such a water code would operate in the East, I do know that it would ultimately place Western and Midwestern water utilities in a position of begging with hat in hand for enough water to serve their customers. This kind of situation would be inevitable in any area where the agricultural interest is politically the most powerful. For instance (and, of course, I admit that this is an extreme example), in one of the recent legislatures in South Dakota, every member save one was a farmer or rancher! Is it any wonder, then, that it took the city of Winner, S.D., some 5 years to get a law which would even permit it to go out of the corporate limits to get a water supply?

I am strongly of the opinion that successful water rights legislation must establish a priority for municipal use of both ground and surface waters second only to that for farmstead (not irrigation) and livestock-watering uses, and I think that that should be the position of the AWWA members individually and collectively.

JOHN W. CRAMER

Chm., Water Resources Div.
Lincoln, Neb.; Aug. 22, 1958

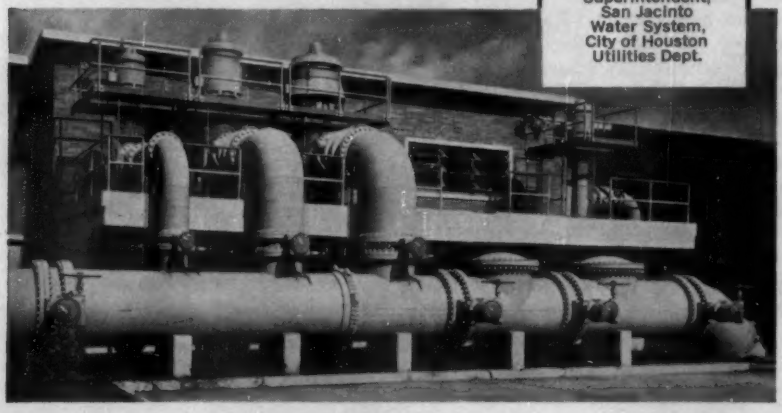
Asked for comment, Dr. Wolman replied:

It is interesting that, while both Mr. Cramer and I start with the same principle—namely, that municipal water supply should have the highest priority in

(Continued on page 92 P&R)

The Houston Water Purification Plant was one of the first plants to use rubber-seated butterfly valves in filter service. Freese, Nichols and Turner, Consulting Engineers, chose R-S Rubber-Seated Butterfly Valves over conventional gate valves for all low-pressure service because their compact design permitted close coupling of pipe. Result: a substantial saving in space, and a direct, in-place cash saving of $124,000.

CLYDE R. HARVILL, Superintendent, San Jacinto Water System, City of Houston Utilities Dept.



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Correspondence

(Continued from page 90 P&R)

allocation—we end up in interpreting the national scene somewhat differently.

I hesitate to have priorities and allocations frozen in legislative acts, because the history of our country indicates that such freezing has been erroneous as often as it has been correct. I am particularly disturbed in having legislatures settle highly technical adjudications, particularly since I know of no state in the Union in which the legislative assembly is not completely dominated by rural agricultural majorities. Their objectivity toward any priorities, other than agricultural, leaves much to be desired, whether in the East or in the West.

It is for this reason that I put most of my confidence in an act setting forth general principles and in an administrative body which ordinarily would have both greater objectivity and higher technical equipment.

Grounded Water

To the Editor:

The task group report on "Developments in Artificial Ground Water Recharge" published in the July issue asserts (p. 869) that in no state is it required to return to the ground cooling water obtained from a municipal supply. It may be of interest to point out that an ordinance adopted by the town board of Hempstead in Nassau County, Long Island, N.Y., permits return to the ground as an alternative to the use of conservation devices on air-conditioning water

(Continued on page 94 P&R)

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Correspondence

(Continued from page 92 P&R)

f.om a public system. Similar legislation applicable to the other public water systems in Nassau County (there are 50 all told, of which seven are privately owned) has been proposed.

W. FRED WELSCH
Sr. Hydraulic Engr., Nassau County Dept. of Public Works
Mineola, N.Y.; Sep. 9, 1958

Wet Jet

To the Editor:

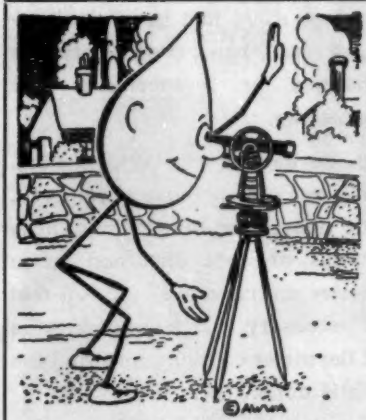
The P&Rticle on the space age (August, p. 50) reminds me of another space smasher water consumer, whose operations came to light recently at Caracas' airport. Pan American Airways' plans to give a group of notables and members of the press a free ride in a new Boeing 707 jet airliner were nearly upset by a water shortage. It seems that the jets require about 1,000 gallons of demineralized water to get up to takeoff power, and only 500 had been provided. But somehow the PAA port manager procured the balance, and the story ended happily.

Moral: For the airman, it's 1,000 gals in every port.

JOHN M. HEPLER
Caracas, Venezuela
Sep. 5, 1958

PAA informs us that demineralized water must be provided in every port of call but one—Boston, Mass., where tap water is satisfactory. No ion would dare misbehave in Boston.—ED.

(Continued on page 98 P&R)



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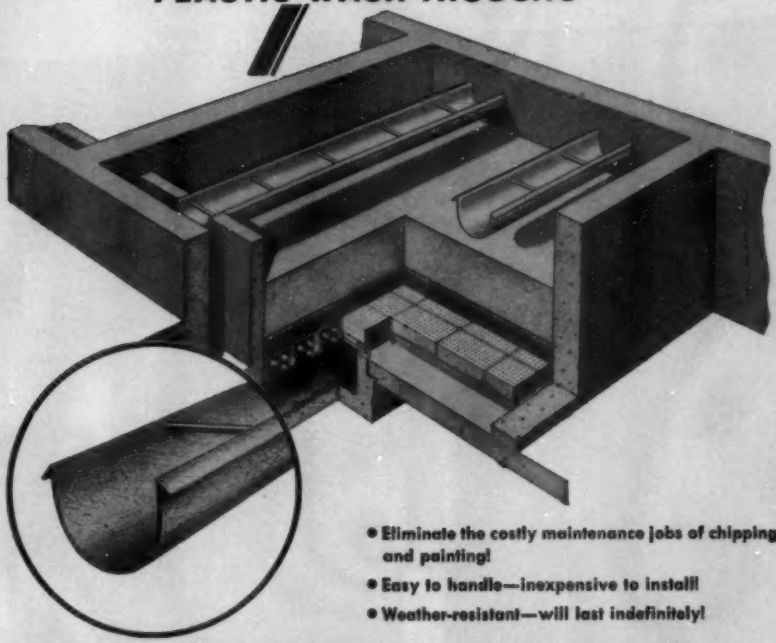

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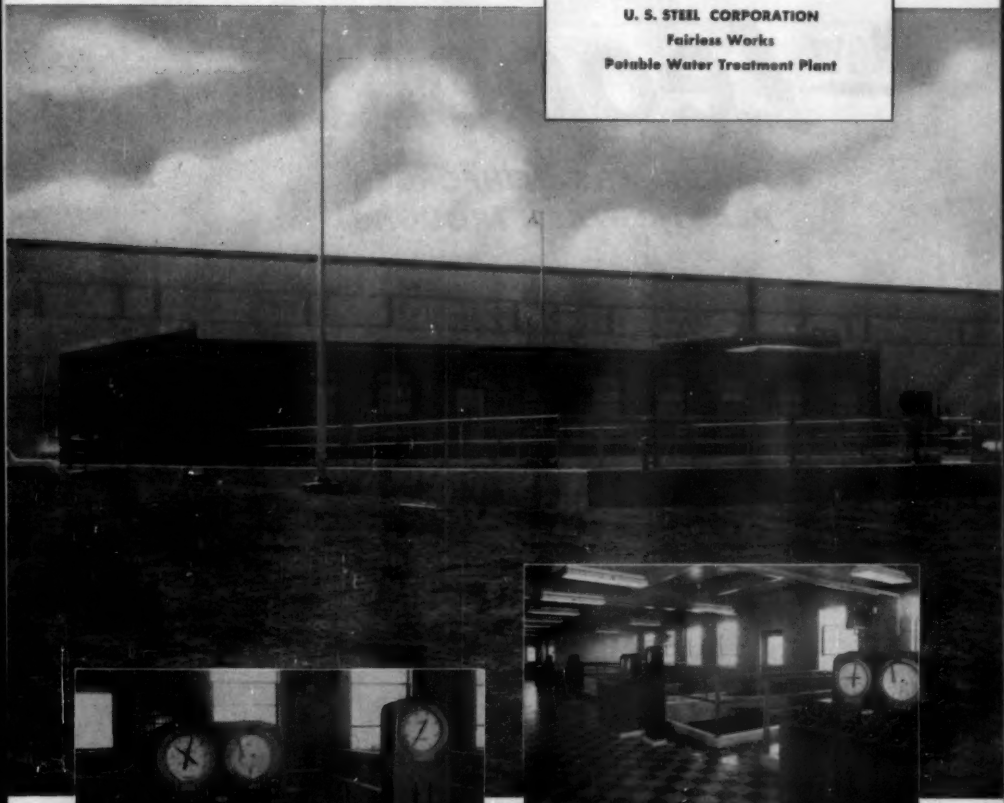

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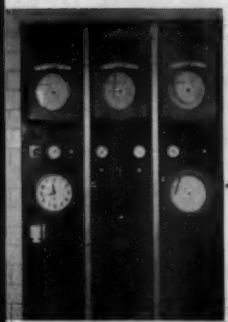

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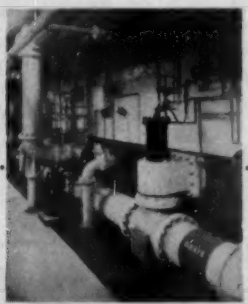

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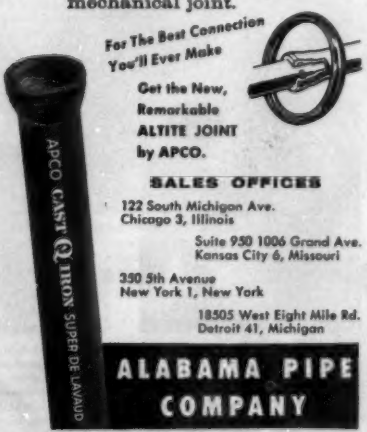

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Correspondence

(Continued from page 94 P&R)

Cu Culprit

To the Editor:

I thought you might be interested in another case of a taste problem due to copper in which a carbonated-beverage vending machine was involved. [In July "Correspondence," p. 52 P&R, D. B. Williams described his difficulties with such a complaint at Brantford, Ont.] This instance occurred at Midland, Mich., and is mentioned in a paper on vending-machine sanitation by Nicholas A. Milone.

A carbonated-beverage machine was connected directly to the water supply, with the result that carbon dioxide escaping from the cylinder backed up into the water line in the building. This led to an acid condition in the water and caused the dissolution of copper from the piping. The water at a drinking fountain in the building exhibited an extremely bitter taste and left a greenish-blue residue after drying on the fountain. To prevent such a situation, Milone writes, it would appear advisable to provide a complete break between the incoming water line and the carbonated water or syrups in the machine.

Milone goes on to mention another taste problem which may occur in such machines. If the carbon filter is not replaced often enough, algae and bacteria may collect and multiply, with resultant deleterious effects on the water, particularly when the number of drinks sold is small.

LUTHER PIBROCH

Acushnet, Mass.
Sep. 4, 1958

The paper referred to is "The Sanitary Appraisal of Automatic Coin-Operated Food and Beverage Vending Machines," presented by Nicholas A. Milone, University of Michigan, at the 1958 annual health conference of the New York State Public Health Assn.—ED.

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Borg, Grant K., Head, Civ. Eng. Dept., Univ. of Utah, Salt Lake City 12, Utah (Jul. '58)

Boynton, E. W.; *see* Northern Gravel Co.

Brown, James B., Sales Engr., Rockwell Mfg. Co., Box 1181, Atlanta 1, Ga. (Jul. '58)

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Campbell, Howard, Lab. Supervisor, Intermountain Chem. Co., Box 372, Green River, Wyo. (Jul. '58)

Caridis, Theodore J., Sales Engr., D. D. Foster Co., 2210 Koppers Bldg., Pittsburgh 19, Pa. (Jul. '58)

Case, Homer W., Supt., Water Dept., Bloomfield Township, 4200 Telegraph, Bloomfield Hills, Mich. (Jul. '58)

Choate, Aaron Crockett, Water Supt., Air Inst., Lackland Air Force Base, San Antonio, Tex. (Jul. '58)

Colorado River Board of Calif., Raymond Matthew, Chief Engr., Room 550, 909 S. Broadway, Los Angeles 15, Calif. (Corp. M. Jul. '58)

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Elmore, Brad, Supt., Munic. Sterilization & Filtration Plant, Vandalia, Ill. (Jul. '58)

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Flood, John H., Jr., Partner, Flood, Wilson & Assocs., Box 5861, 1526 Hendricks Ave., Jacksonville 7, Fla. (Oct. '51)

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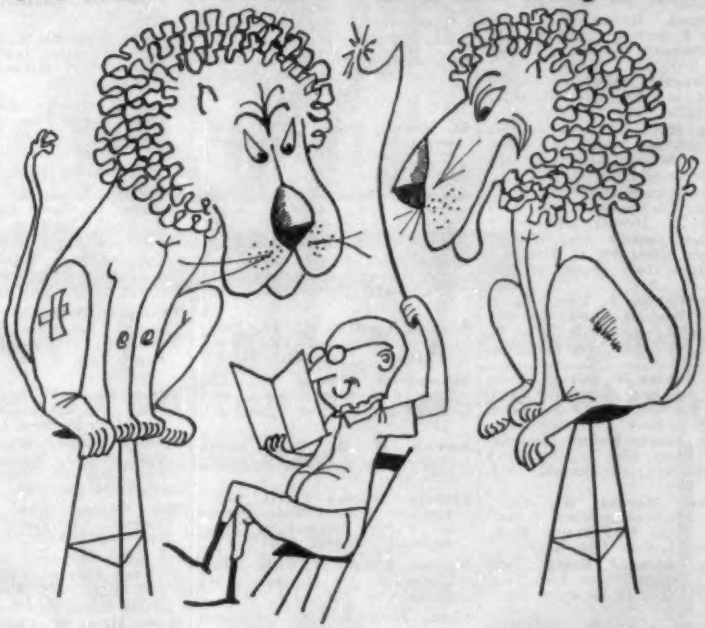

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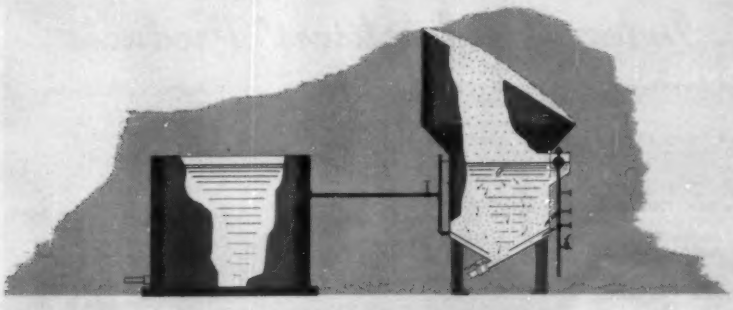

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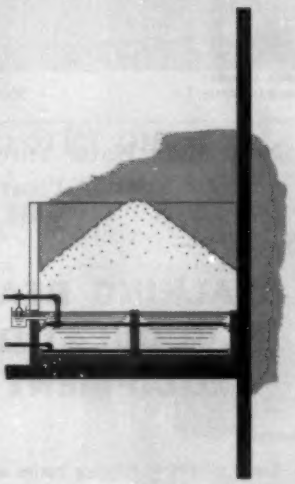

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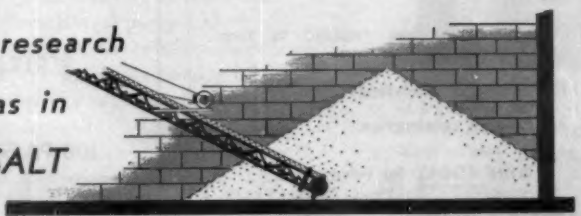

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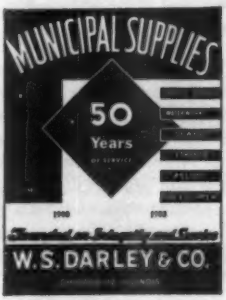

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Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Bailey Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Foster Eng. Co.
Simplex Valve & Meter Co.
Sparling Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Bailey Meter Co.
Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
F. B. Leopold Co.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Steel:
Alco Products, Inc.
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.

Pipe Cleaning Services:
National Water Main Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div.
Reilly Tar & Chemical Corp.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
Precision Chemical Pump Corp.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
W. S. Rockwell Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Bailey Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Simplex Valve & Meter Co.
Sparling Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Permutit Co.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

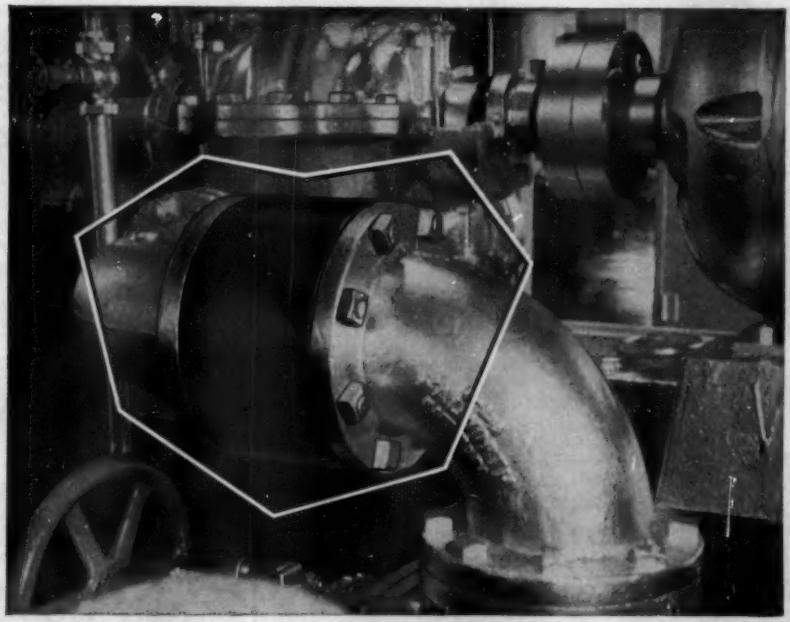
Sodium Silicate:
Philadelphia Quartz Co.

Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
Industrial Chemicals, Inc.
International Salt Co., Inc.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.



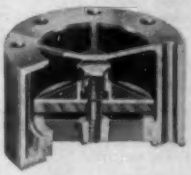
ELIMINATE BACK-DROP, SURGE AND HAMMER

When CPV silent, non-slam check valves are installed on the discharge of centrifugal pumps, the whole system is protected against waste and harmful surges. The need for expensive air cushions and other anti-hammer devices is eliminated.

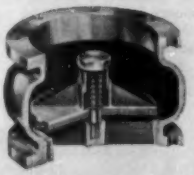
Spring-actuated, CPV check valves close automatically as soon as flow ceases. Back travel, which can be so damaging, is not required for closing.

Users report CPV valves easy to install and require no maintenance. Unique design includes bearing guides on both sides of disc and a full flow area in excess of pipe area. The valve operates in any position.

For complete specifications and prices write Combination Pump Valve Company, 853 Preston Street, Philadelphia 4, Pa.



STYLE "G"—2 to 10"



STYLE "GB"—6" and up

CPV SILENT NON-SLAM CHECK VALVES

Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Steel Plate Construction:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Stops, Curb and Corporation:
Hays Mfg. Co.
Mueller Co.

Storage Tanks: see Tanks

Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.

Surface Wash Equipment:
Permutit Co.

Swimming Pool Sterilization:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Omega Machine Co. (Div., B-I-F Industries, Inc.)
Proportioneers, Inc (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

Tanks, Steel:
Alco Products, Inc.
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.

Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

Taste and Odor Removal:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.

Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Turbines, Water:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.

Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Golden-Anderson Valve Specialty Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.
S. Morgan Smith Co.

Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Detector Check:
Hersey Mfg. Co.

Valves, Electrically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.

Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Hydraulically Operated:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Large Diameter:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Regulating:
DeZurik Corp.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Venturi Tubes:
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Simplex Valve & Meter Co.

Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div.

Water Softening Plants; see Softeners

Water Supply Contractors:
Layne & Bowler, Inc.

Water Testing Apparatus:
LaMotte Chem. Products Co.
W. A. Taylor & Co.
Wallace & Tiernan Inc.

Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.

Well Drilling Contractors:
Layne & Bowler, Inc.

Wrenches, Ratchet:
Dresser Mfg. Div.

Zeolite: see Ion Exchange Materials

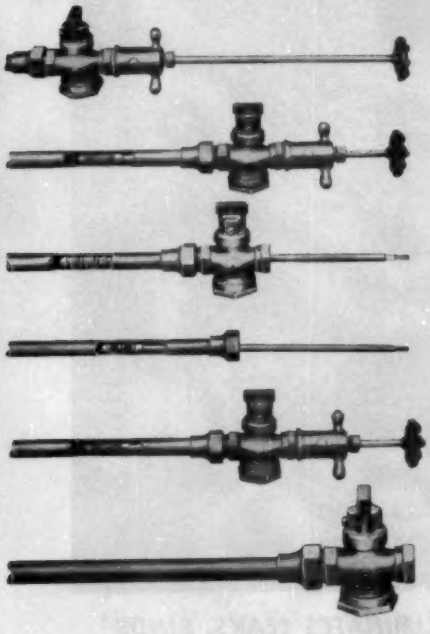
A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1957 AWWA Directory.

PIPE LINE EQUIPMENT

Now—with an AQUA-STOP you can change leaking or defective curb stops under pressure

Think of it!

with the simple tool shown you can replace old or leaking curb stops under full pressure! No breaking into expensive roadways. Only one hole to dig—and no water or mud!



In six easy steps, as simple as this!

1. Insert the AQUA-STOP in the outlet side of the curb stop.

2. Push the plunger through the open curb stop. Turn the hand wheel on the AQUA-STOP, and all flow through the line is stopped.

3. Remove the body of the AQUA-STOP.

4. Remove the curb stop. The AQUA-STOP will hold the full line pressure as long as you want it to.

5. Replace the curb stop with a good one, replace the AQUA-STOP body, again turn the hand wheel, and withdraw the plunger.

6. Turn off the new curb stop, remove the AQUA-STOP and the job is done. Only a cup of water lost! And SO SIMPLE TO OPERATE.

AQUA-STOP FOR ¾" CURB STOPS, COMPLETE WITH IRON PIPE THREAD OUTLET AND FLARE-TYPE COPPER TUBE OUTLET.
Complete $27.95

PIPE LINE EQUIPMENT

JOSEPH G. POLLARD CO., INC.

PIPE LINE EQUIPMENT

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If it's from POLLARD . . . It's the Best in Pipe Line Equipment

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EXCLUSIVE* CONSTRUCTION ELIMINATES LEAKS, BINDS

Rockwell "O"-Ring stuffing box nuts provide a *leak tight seal* on the register drive spindle. This seal is accomplished with *very slight compression*, so friction becomes negligible and meter performance is actually improved. This construction is *foolproof*, since the "O"-Ring nut can be force tightened with a wrench without applying any additional compression.

Seven years of field experience have proved the success of this *exclusive* Rockwell development—now furnished as standard construction on Rockwell meters at no additional cost. And Rockwell "O"-Ring stuffing box nuts are available as interchangeable replacement parts for earlier model Rockwell meters. Ask your Rockwell representative to demonstrate. Rockwell Manufacturing Co., Pittsburgh 8, Pa.

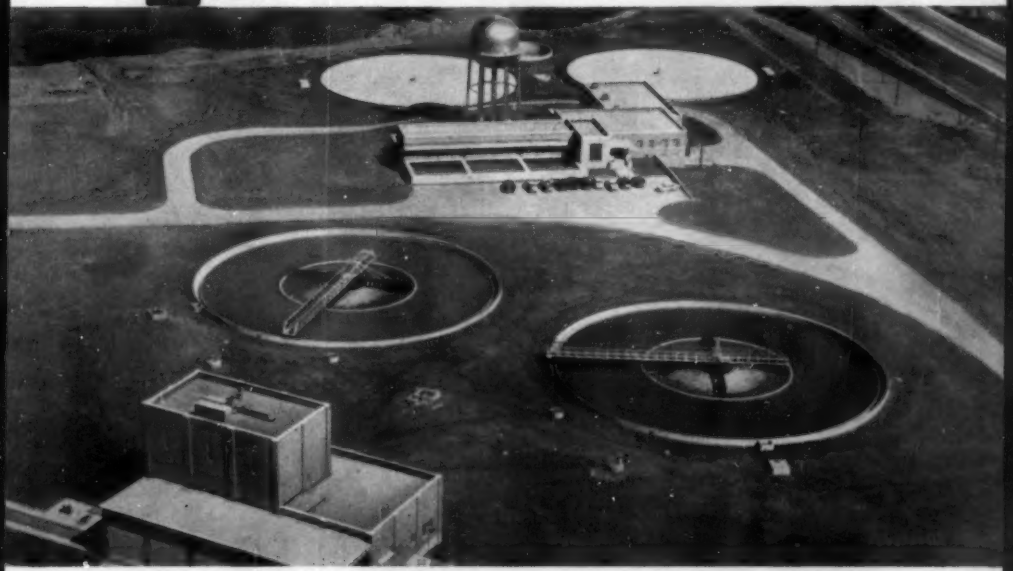
*Patented

WATER METERS
another fine product by
ROCKWELL

The solution to this problem is always the same . . . but

Water Treatment Problems are different

No two water treatment problems are exactly alike. The right solution to each can be arrived at only after a careful study of local conditions. Variables such as raw water consumption, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to suit the job . . . and not vice versa.



North Texas Municipal Water District

World's largest Clariflocculators

Each 170-ft. in diameter and having a 14-ft. swd, the Dorr-Oliver Clariflocculator units shown above are two of the world's largest. Each unit provides for a 66 minute flocculation period and a settling period of 4.53 hours at a plant output rate of 20 MGD. This installation at Wylie, Texas, for the North Texas Municipal Water District, is another example of the widespread preference for Dorr-Oliver equipment. For information, Write to Dorr-Oliver Inc., Stamford, Connecticut.

Consulting Engineer: Forrest & Cotton, Dallas, Texas.
Design Engineer: Ormond A. Stone, Dallas, Texas.
General Contractor: C. H. Leavell & Co., El Paso, Texas.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
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*Clariflocculator—T.M. Reg. U.S. Pat. Off.

LEADITE

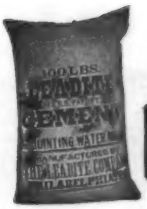
Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%



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No Caulking